Model 6620

10Hz to 10MHz
IEEE-488 Remote Control
Precision Phasemeter

KROHN-HITE CORPORATION

Operating/Maintenance Manual

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10Hz to 10MHz IEEE-488 Programmable Precision Phasemeter

MODEL 6620

SERIAL NO. 500

OPERATING AND MAINTENANCE MANUAL

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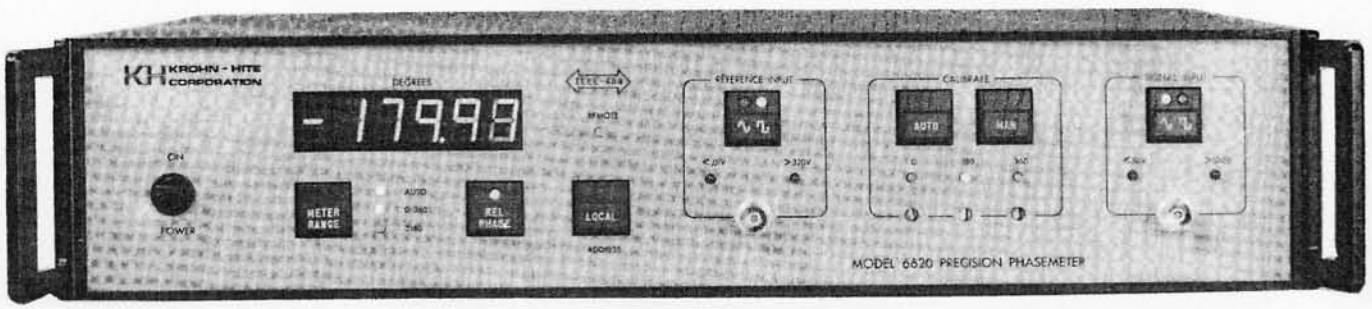


Figure 1 Model 6620 Precision Phasemeter

SECTION 1
GENERAL DESCRIPTION

1.1 INTRODUCTION

The Model 6620 Programmable Precision Phasemeter measures the phase angle between two waveforms of coincident frequency, over a range of 10Hz to 10MHz, with a typical accuracy of 0.02° and 0.01° resolution. It will accept a wide range of input signal levels automatically without range switching from 10 millivolts to 320 volts rms, and input waveforms of sine, square, triangle, and pulses of >50ns. A 5 digit, LED display provides continuous direct readout of phase angles between 0.00° and 360.00°, or ±180°. These two ranges can be selected either manually or automatically. An analog output which provides a dc voltage equal to 10mv/° for use with an external meter or recorder.

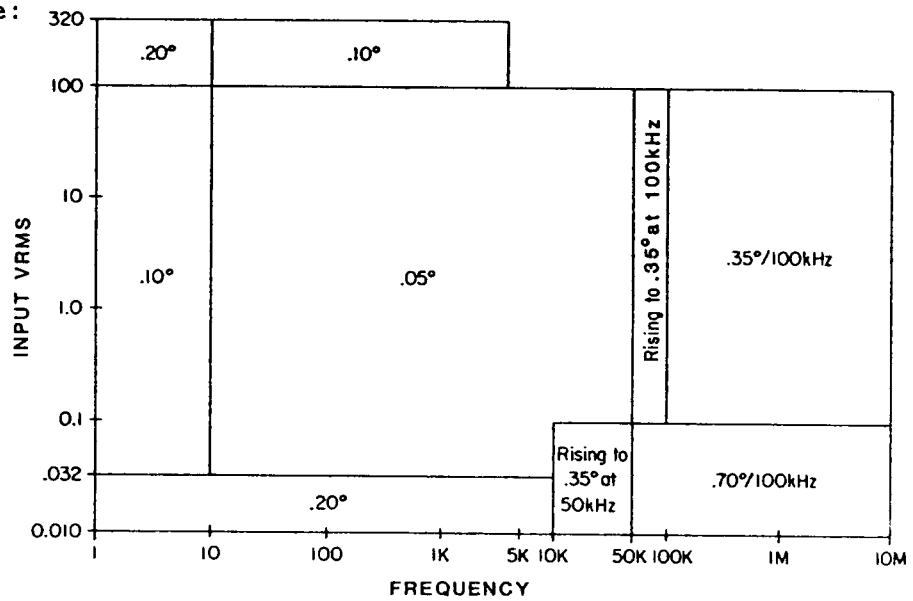
The 6620 also provides a RELATIVE measurement mode which allows the monitoring of phase deviations, front panel indicators to indicate a too low/high input voltage range.

The Model 6620 is carefully inspected, aged, and adjusted before shipment, and ready for operation when unpacked. If it has been damaged in shipment, make a claim with the carrier and notify Krohn-Hite immediately.

1.2 SPECIFICATIONS

FREQUENCY RANGE: 10Hz to 10MHz (1Hz Optional).
PHASE MODE: Absolute or Relative.
ACCURACY

Sine Wave:



Square Wave: Double the sine wave specification.

INPUT

Signal Amplitude: Auto ranging from 0.01 Volts to 320 volts rms.

Waveforms: Sine, triangle, square and >50ns pulse (The phasemeter is triggered on the positive going transition of the input waveform. Sine wave on the reference input and square wave on the signal input is allowed).

Impedance: 1 Megohm in parallel with a 50pf.

Maximum dc Component: ±200 volts.

RESPONSE

Time Constant: >10Hz, less than 500msec; <10Hz, less than 5sec.

Settling Time: To within specified accuracy, within 1 to 8 seconds, dependent on input amplitude and frequency (>10Hz).

DRIFT

Vs. Time: (30 days without AMC and CALIBRATE reset) Sine Wave, ±0.025° from 20Hz to 100kHz; ±0.1° at 10Hz; ±0.1° per 100kHz above 100kHz. Square Wave, ±0.025° from 10Hz to 5kHz; ±0.05° to 100kHz; ±0.1° per 100kHz above 100kHz.

Vs. Temperature: (Without AMC and CALIBRATE reset) ±0.01°/°C, 10Hz to 100kHz; ±0.05°/°C to 1MHz; ±0.05°/°C per MHz above 1MHz.

ANALOG OUTPUT: (for use with an external meter or recorder) 0-3.6 or ±1.8 volts DC, 10mV DC/degree phase, impedance 50 ohms.

DISPLAY: 0.5", 7 segment, green LED.

DISPLAY RANGES: Automatic, 0.00° to 360.00° or ±180.00°.

RESOLUTION: 0.01°.

REPEATABILITY: Better than 0.01°.

POWER CABLE: 7 feet, removable.

DIMENSIONS: 3.5"/(9cm) high, 16.5"/(41.9cm) wide, 16"/(40.6cm) deep.

WEIGHTS: Net 15 lbs/(6.75kg), Shipping 18 lbs/(8.1kg).

AMBIENT TEMPERATURE RANGE: 0°C to 50°C.

FRONT PANEL CONTROLS: POWER, METER RANGE, REL PHASE, Reference Waveform, Signal Waveform, CALIBRATE (AUTO and MAN), phase adjust (0°, 180° and 360°).

POWER REQUIREMENTS: 90-132V or 198-264V, single phase, 50-400Hz, 40W.

OPTIONS

RK-316: Rack Mount Kit for a standard 19" rack spacing.
Option 002: 1Hz operation.
Option 003: Rear panel BNC connectors for REFERENCE and SIGNAL inputs.

Specifications are subject to change without notice.

1.3 TYPICAL PERFORMANCE

Typical performance of the Model 6620 is shown in Figure 1.1 with matched inputs. The graph with interrupted lines is the specified response with unmatched inputs over the input range of 0.1 to 100V.

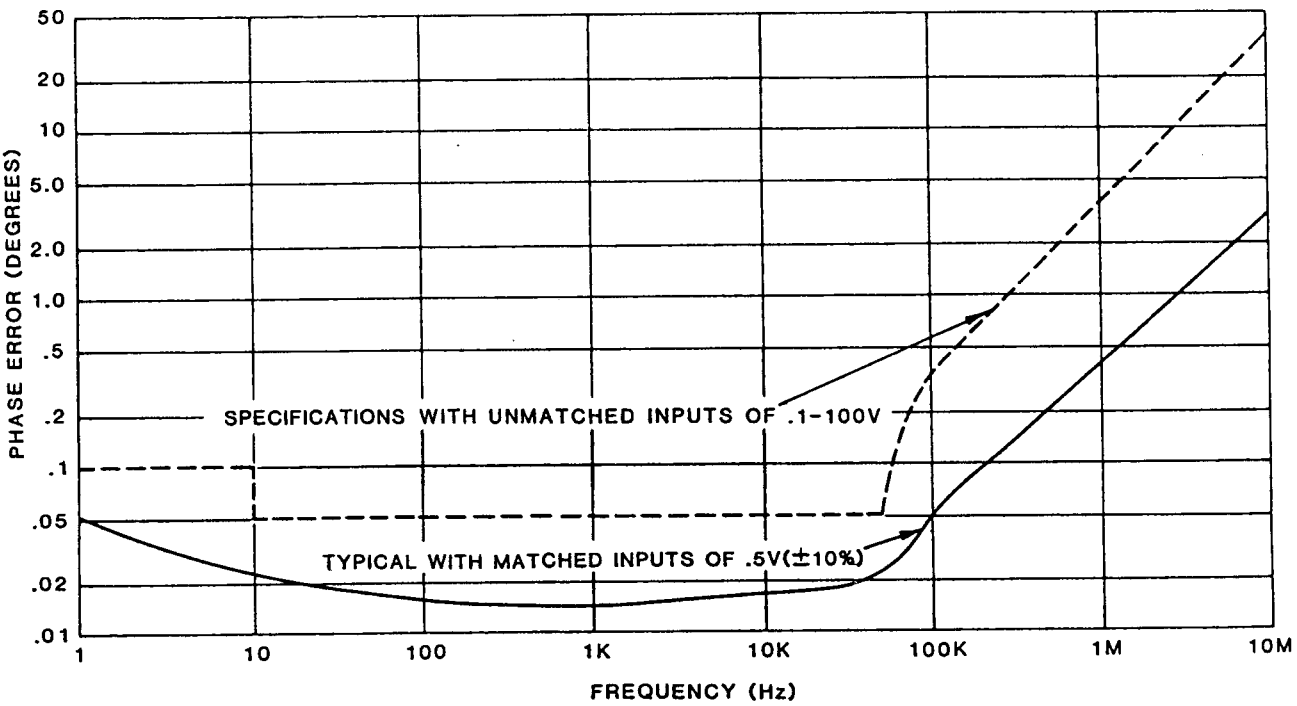


Figure 1.1 Typical Performance

1.4 FACTORS AFFECTING PHASEMETER ACCURACY

1.4.1 Inconsistencies In Meter Reading Near 0° and 360°

A problem affecting a phasemeter's accuracy is the inability of the phasemeter circuit to detect relatively small phase angles, resulting in meter fluctuations or inconsistencies in meter readings. The 6620 overcomes this inconsistency (or ambiguity as it is sometimes referred to) by using a specially designed network that permits measurements as small as 0.01° to be made without meter fluctuations or repeatability errors, and eliminates the need for multiple meter ranges, or shifting of the meter scale.

1.4.2 Noise Present On The Input Signals

Another problem affecting phase accuracy is random noise. If there is a sufficient noise level on either or both inputs, false triggering will occur and a phase error is introduced. The 6620 uses special circuits plus filtering to minimize the effects of noise on the phase accuracy. Typically, any broadband noise present on both inputs 40dB down from the input signals will produce only a 0.05° error. Figure 1.2 gives a typical curve for phase error versus input frequency, for a signal to noise ratio of 10:1 on both inputs.

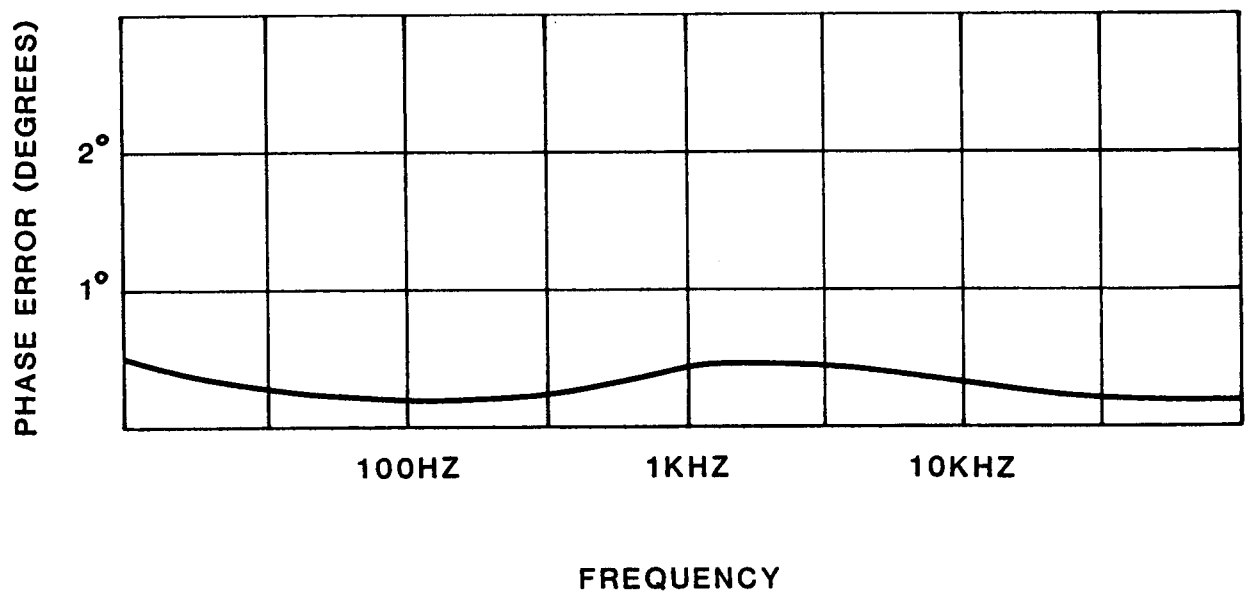


Figure 1.2 Phase Error vs. Random Noise

1.3.3 Distortion Present On The Input Signal

If there is distortion present on one of the input signals, a phase error may be introduced, depending upon the relationship between the fundamental and its harmonics. If the amplitude of all the odd or even harmonics add up to zero at the positive zero crossing of the fundamental, then the harmonics will produce no phase error. If the resultant of the amplitudes is not zero, however, it will cause a shift in the zero crossing of the input waveform. Worst case would occur when the maximum of the harmonic coincides with the positive zero crossing of the fundamental. The effect of an even harmonic will not only shift the zero crossing of the waveform, but also alter the symmetry of the comparator or detector output. If a symmetry control loop is added to the phasemeter circuit, the effect of the even harmonic on accuracy can be minimized. The 6620 uses the type of symmetry loop mentioned above.

The effect of an odd order harmonic is not as easily corrected. An odd order harmonic simply shifts the phase of the output of the comparator or detector loop. Since the symmetry is not affected, there is no way to detect any phase error. Figure 1.3 shows the maximum phase error introduced versus the percentage of harmonic distortion present on each input channel.

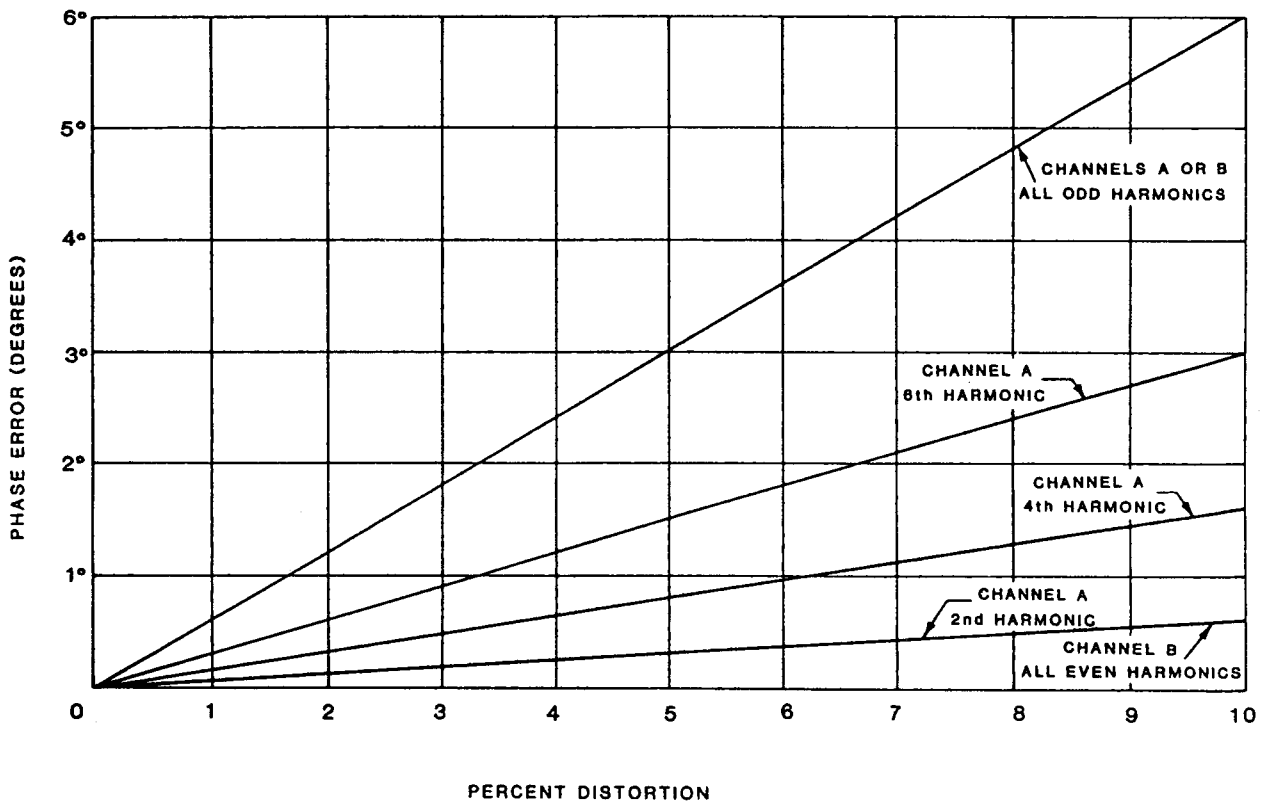


Figure 1.3 Maximum Phase Error vs. % Harmonic Distortion

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SECTION 2
OPERATION

2.1 INTRODUCTION

This section describes the basic operation of the Model 6620. It includes the proper ac power requirements, the recommended turn-on procedure and a detailed explanation of all operating controls and modes of operation.

2.2 POWER REQUIREMENTS

The Model 6620 is designed to operate from a single phase, 50-400Hz ac power source of 90-110, 108-132, 198-244 or 216-264 volts. Line switches on the rear panel allow it to be powered from one of the above 4 voltage ranges. The ac power receptacle, on the rear panel, is a standard 3-pin connector and complies with the European I.E.C. standard. The fuse receptacle contains a 3/4 ampere slo-blow fuse for 120V operation and a 3/8 ampere slo-blow fuse for 240V operation. A detachable line cord is provided with the instrument.

2.3 TURN-ON PROCEDURE

1. Set the line switches for the correct voltage range and check to see that a fuse with the correct rating is in the fuse receptacle.

   For 90-110 volts, set the 120V/240V switch to 120V and the NORM/LO switch to LO. The fuse should be 3/4 amp.

   For 108-132 volts, set the 120V/240V switch to 120V and the NORM/LO switch to NORM. The fuse should be 3/4 amp.

   For 198-244 volts, set the 120V/240V switch to 240V and the NORM/LO switch to LO. The fuse should be 3/8 amp.

   For 216-264 volts, set the 120V/240V switch to 240V and the NORM/LO switch to NORM. The fuse should be 3/8 amp.

2. Make sure that the POWER switch is in the OFF position.
3. Plug the line cord into the unit and into an ac outlet.
4. Turn the power on and allow it to warm-up for several minutes.

CAUTION

For safety purposes, the line cord must be connected to a grounded 3 terminal ac outlet. Because of potentially dangerous voltages that exist within the unit, the cover should be removed by qualified personnel only.

2.4 FRONT PANEL CONTROLS, CONNECTORS AND INDICATORS

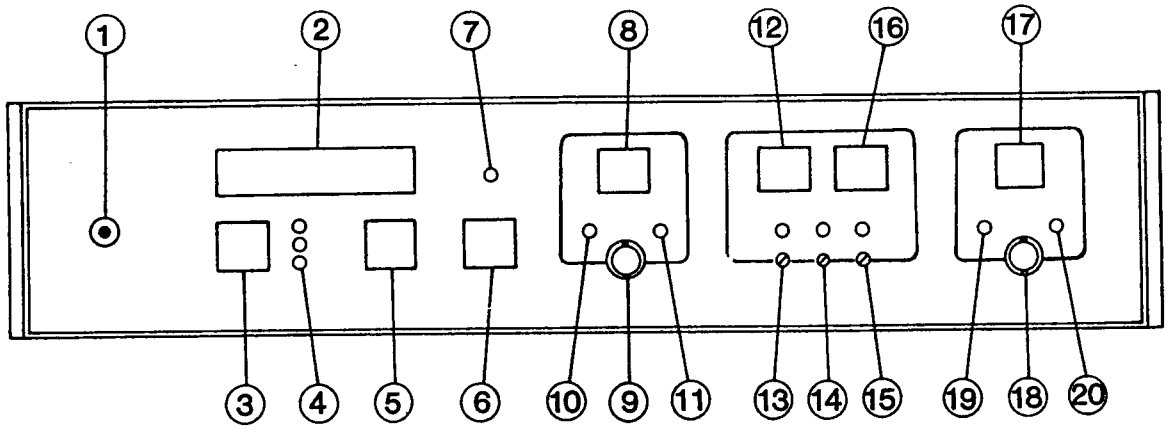

Figure 2.1 Front Panel Controls, Connectors and Indicators

1. POWER — On/Off toggle switch.

2. DISPLAY — 5 digit, green LED, 0.55" high.

3. DISPLAY RANGE — Selects desired range of AUTO, 0-360°, or ±180°.

4. LED INDICATORS — Indicates display range in use; AUTO, 0-360° or ±180°.

5. REL PHASE — Selects RELATIVE display mode. When pressed, the DISPLAY will indicate 0.00°.

6. LOCAL — This key has two separate functions. One in remote operation and the other in local operation.

   a. In remote operation, pressing the [LOCAL] key will return the unit to local operation. The LED indicator under REMOTE will turn off.

   b. In local operation, pressing the [LOCAL] key will display menus for setting GPIB or RS-232 configuration. See Section 3.

7. LED INDICATOR — Indicates REMOTE operation.

8. WAVEFORM — Selects desired waveform applied to REFERENCE input.

9. REFERENCE INPUT — BNC, 10mV to 320Vrms.

10. LED INDICATOR — Indicates REFERENCE input is <10mVrms.

11. LED INDICATOR — Indicates REFERENCE input is >320Vrms.

12. AUTO — Selects AUTO METER CORRECT (AMC) mode. When pressed, the unit will cycle through and automatically calibrate the display at 0°, 180° and 360°, and respective LEDs will light intermittently. This feature will not calibrate the analog output of the unit, only the display.

13. 0° CONTROL & LED INDICATOR — Indicates control for 0° calibration can be adjusted.

14. 180° CONTROL & LED INDICATOR — Indicates control for 180° calibration can be adjusted.

15. 360° CONTROL & LED INDICATOR — Indicates control for 360° calibration can be adjusted.

16. MANUAL — When pressed, the 0° LED indicator will light intermittently. Adjust screwdriver control positioned below 0° LED so DISPLAY indicates 0.00°. When pressed again, the 180° LED indicator will light intermittently. Adjust screwdriver control positioned below 180° LED so that DISPLAY indicates 180.00°. When the 360° adjustment is made in a similar manner, pressing the [MAN] key will return the unit to normal operation.

17. WAVEFORM SELECT — Selects desired waveform applied to the SIGNAL input.

18. SIGNAL INPUT — BNC, 10mV to 320Vrms.

19. LED INDICATOR — Indicates SIGNAL input is <10mVrms.

20. LED INDICATOR — Indicates SIGNAL input is >320Vrms.

2.5 REAR PANEL CONTROLS AND CONNECTORS

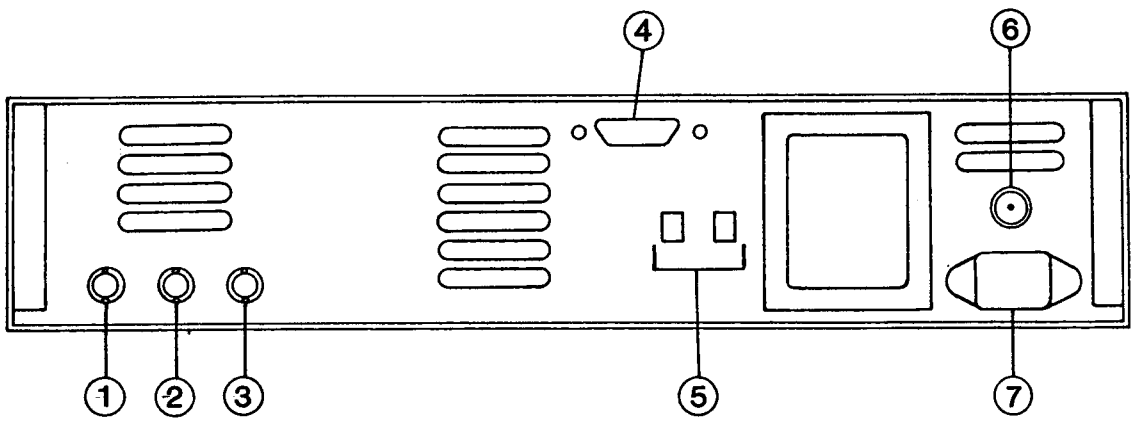

Figure 2.2 Rear Panel Controls and Connectors.

1. SIGNAL INPUT — BNC (optional), 10mV to 320Vrms.

2. REFERENCE INPUT — BNC (optional), 10mV to 320Vrms.

3. ANALOG OUTPUT — BNC, 0 to 3.6Vdc, 10mV/°. Impedance 50 ohms.

4. IEEE-488 PORT — Standard IEEE-488 interface connector (Uses metric hardware) or optional RS-232 (uses standard hardware).

5. LINE — Slide switches to select 120V or 240V operation, and NORMAL or LOW ac line.

6. FUSE RECEPTACLE — 3/4 amp for 120V operation, 3/8 amp for 240V operation.

7. AC POWER RECEPTACLE — standard 3 Pin Receptacle.

2.6 OPERATION

To operate the Model 6620 proceed as follows:

1. Make the appropriate power connections to the unit. Turn the power on and let the unit warm up for at least 30 minutes to achieve the rated accuracy and eliminate any drift that may be caused due to temperature variations.

2. Pressing the [MAN] key momentarily will light the 0° LED indicator intermittently. Adjust the screwdriver control below the LED so display indicates 0.00°.

   Pressing the [MAN] key momentarily again will light the 180° LED intermittently. Adjust the screwdriver control below the 180° LED so DISPLAY indicates 180.00°.

   Pressing the [MAN] key momentarily again will light the 360° LED intermittently. Adjust the screwdriver control below the 360° LED so DISPLAY indicates 360.00°. When the [MAN] key is momentarily pressed, the DISPLAY will return to normal operation.

After the unit has warmed up and the initial calibration was done to the phasemeter, connect the reference signal to the REFERENCE INPUT and the signal to be measured to the SIGNAL INPUT.

When the input cables are connected to the proper inputs, press the WAVEFORM key on each channel to select the desired input waveform. If the [sine] is selected, the phasemeter will measure phase angles between sine waves, a sine and triangle wave, or triangle waves. If the [square] is selected, the phasemeter will measure squarewaves and/or pulses. Pulse widths must be >50ns. It is recommended, however, that when a [sine] is selected with a [square], that the sine wave, which will be the cleanest signal, be connected to the REFERENCE INPUT. If a sinewave is used when [square] is selected, an error of several degrees can be expected.

NOTE

It is recommended that matched, equal length, coaxial cables be used, as a difference in length may affect the phasemeter accuracy, especially at higher frequencies. As an example, two cables of the same type (approximately 30pf/ft), but differing in length by one foot will create an error at 100kHz of about 0.06°.

After selecting the proper WAVEFORM, check to see that the LED above the REFERENCE and SIGNAL inputs are off. When the input voltage is less than 10mV rms (<.01V) or greater than 320V rms (>320V), the appropriate LED will light to indicate the too low/high condition. If either LED is on, adjust the input voltage level until the LED turns off.

When the input voltages are adjusted to within the limits of the phasemeter, select the METER RANGE. There are three modes of operation; AUTO, 0-360°, and ±180°.

1. AUTO — In this mode, the phasemeter will switch ranges automatically between 0-360 or ±180. If the phasemeter is in the 0-360 range, and the phase angle being measured is approaching 10.00° or 350.00°, the phasemeter will automatically switch to the ±180 range. When in the ±180° range and the phase angle being measured approaches +170.00° or −170.00°, the phasemeter will automatically switch to the 0-360° range. This feature allows the user to continuously measure phase angles without interruption.

2. 0-360 — This range will measure phase angles between approximately −5.00° and 365.00°. For phase angle measurements exceeding 360.00°, the DISPLAY will remain in the 360.00° range until the reading is approximately 365.00°. The phasemeter will then switch to the low end of the range, and the DISPLAY will indicate a phase of approximately 5.00°.

   Conversely, if the phase angle being measured is less than 0.00°, the DISPLAY will remain in the 0.00° range until the reading is approximately −5.00°. The phasemeter will then switch to the high end of the range, and the DISPLAY will indicate approximately 355.00°.

3. ±180 — This range operates in the same manner as the 0-360° range, and will measure phase angles between approximately −185.00° and +185.00°. For phase angle measurements exceeding +180.00°, the DISPLAY will remain in this range until the phase is approximately +185.00°. The phasemeter will then switch to the −180.00° range and the DISPLAY will indicate approximately −175.00°.

   Conversely, if the phase angle being measured exceeds −180.00°, the DISPLAY will remain in the −180.00° range until the reading is approximately −185.00°. The phasemeter will then switch to the +180° range, and the DISPLAY will indicate approximately +175.00°.

2.7 DEVIATION MEASUREMENTS

The Model 6620 provides a mode for measuring relative phase deviations. When the [REL PHASE] key is pressed, the phasemeter display will indicate 0.00°. This is the reference point of the phasemeter. When the signal changes in phase, the DISPLAY will indicate phase deviation of the signals being measured.

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SECTION 3
REMOTE PROGRAMMING

3.1 INTRODUCTION

The Model 6620 is compatible with the IEEE-488 Standard Interface Bus (GPIB) or the Electronic Industries Association (EIA) RS-232C Interface Standard. Section 3.2 is relevant to the IEEE-488 and Section 3.3 defines the RS-232C.

3.2 GPIB PROGRAMMING

3.2.1 INTRODUCTION

The Model 6620 remote programming interface accepts both ASCII data commands and IEEE-488 standard commands (ANT true) for control of the unit.

In presenting the information required to program the Model 6620 via the IEEE-488 interface, this manuals pre-supposes a user knowledge of both ASCII data and IEEE-488 bus commands.

3.2.2 IMPLEMENTATION SUB SET

IDENTIFICATION AND CAPABILITIES

SH1	Complete source handshake.
AH1	Complete acceptor handshake.
T6	Basic talker, no talk-only mode, talker is un-addressed when unit is addressed to listen.
L4	Basic listener, no listen-only mode, listener is un-listened when unit is addressed to talk.
SR1	Service requested when any out of range condition occurs.
RL1	Complete Remote/Local and Local lockout control.
PP1	Complete parallel poll capabilities.
DC1	Complete device clear capabilities.
DT0	No device trigger.
C0	No controller capability.
E1	Open collector drivers.

3.2.3 IEEE-488 ADDRESS AND LINE TERMINATION PROCEDURE

The GPIB Address is set via the front panel keyboard. When the phasemeter is not in remote operation (LED indicator off), pressing the [LOCAL] key momentarily will display menu 1 for setting the GPIB address (Figure 3.1). Once the menu is displayed, pressing the [METER RANGE] key will increase the address number and pressing the [REL PHASE] key will decrease the address number.

After the GPIB Address is set, pressing the [LOCAL] key momentarily again will display menu 2 for setting the line termination. Once again, pressing the [METER RANGE] key and/or the [REL PHASE] key will select the desired line termination configuration (refer to Figure 3.2 below).

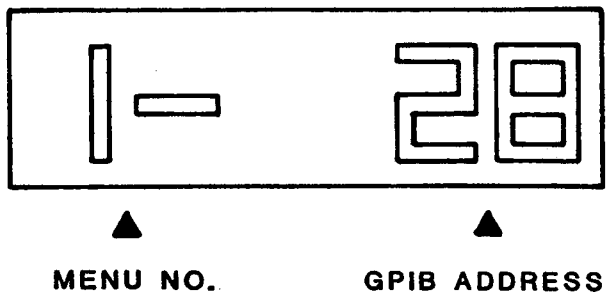

Figure 3.1 GPIB Address

Choices	Description
Cr	Carriage Return
LF	Line Feed
CrLF	Carriage Return/Line Feed
LFCr	Line Feed/Carriage Return
nOnE	No Termination

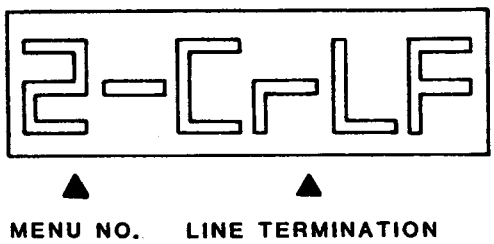

Figure 3.2 Line Termination

3.2.4 IEEE-488 BUS DATA TRANSFERS

RECEIVE COMMANDS

The Model 6620 must first receive its primary listen address. This is followed by the desired command. The commands are executed immediately upon receipt. This means no termination character or EOI message is needed, however, these may be sent if desired.

The following chart indicates the ASCII characters that must be received to operate the various controls.

ASCII CODE	CONTROL FUNCTION
M1	Auto Range Mode
M2	360° Range Mode (non-auto)
M3	180° Range Mode (non-auto)
P0	Non-Relative Phase Mode
P1	Relative Phase Mode
R1	Reference Channel = Sine Wave
R2	Reference Channel = Square Wave

ASCII CODE	CONTROL FUNCTION
S1	Signal Channel = Sine Wave
S2	Signal Channel = Square Wave
T0	No Line Termination
T1	Line Termination = <CR>
T2	Line Termination = <LF>
T3	Line Termination = <CR><LF>
T4	Line Termination = <LF><CR>
Q0	Service Request Off
Q1	Service Request On
Q2	Query Status
C1	Manual 0° Calibration
C2	Manual 180° Calibration
C3	Manual 360° Calibration
C4	Auto Calibration

NOTE: It is necessary to perform an Auto Calibration to leave Manual Calibration mode.

SEND DATA

The Model 6620 must first receive its primary talk address. It will then send a "space" followed by the data and terminated by the selected line-termination codes. The last character is sent with the EOI line true. The data to be sent is in the front panel display, except after receipt of the "Q2" Query Status command.

The following chart indicates the format of the STATUS data sent by the Model 6620. Position is indicated from left to right, thus, "1-Signal Channel Mode" references the MSD of the status word.

1 SIGNAL CHANNEL MODE
- 1 = sine wave
- 2 = square wave

2 SIGNAL CHANNEL ERROR INDICATORS
- 0 = signal channel within range (No Error)
- 1 = signal channel under range
- 2 = signal channel overload error

3 REFERENCE CHANNEL MODE
- 1 = sine wave
- 2 = square wave

4 REFERENCE CHANNEL ERROR INDICATORS
- 0 = reference channel within range (No Error)
- 1 = reference channel under range
- 2 = reference channel overload error

5 PHASEMETER RANGE INDICATORS
- 1 = manual range mode/360° range
- 2 = manual range mode/180° range
- 3 = auto range mode/360° range
- 4 = auto range mode/180° range

6 RELATIVE PHASE MODE INDICATOR
0 = absolute phase mode
1 = relative phase mode

7 CALIBRATION INDICATORS
0 = no calibration LEDs lit
1 = 0° calibration LEDs lit
2 = 180° calibration LED lit
3 = 360° calibration LED lit

DEVICE CLEAR

Since the manual keyboard is capable of leaving the Model 6620 in either the SET GPIB ADDRESS/LINE TERMINATION MODE or a CALIBRATION MODE, the DEVICE CLEAR instruction (DCL) should be employed at the start of a GPIB sequence. DCL will put the instrument into AUTO RANGE/0-360 RANGE, NON-RELATIVE PHASE ANGLE MODE, SIGNAL/REFERENCE CHANNEL SINE WAVE MODE, as well as resetting instrument to PHASE ANGLE DISPLAY and NON-CALIBRATION MODE.

3.2.4 IEEE-488 STANDARD COMMANDS

These commands are sent with ATN true as described in the Standard.

3.2.4.1 MULTI-LINE MESSAGES

IEEE-488 COMMAND	MNEMONIC	RESULT
My Listen Address	MLA	Enables unit to receive data.
Unlisten	UNL	Disables all units from receiving data.
My Talk Address	MTA	Designates unit to send data.
Untalk	UNT	Disables all units from sending data.
Local lockout	LLO	Disables return to local key on front panel such that only the controller can activate the front panel keyboard.
Go To Local	GTL	Puts unit into local control mode such that front panel keyboard is activated.
Device Clear	DCL	Returns all units to power on conditions.
Selected Device Clear	SDC	Performs same functions as Device Clear (DCL) except only if unit is addressed.

Discussion: (See Section 2.8 and Figure 10 of the IEEE-488 Interface Standard).

Note that there are 4 possible states; local, remote, local-with-lockout and remote-with-lockout. Front panel control is considered to be local, while control from the "bus" is considered to be remote. When the unit is addressed to listen (MLA), it goes into remote. When Go To Local (GTL) is sent, it goes into local. Also, if lockout mode is not set by the controller, local lockout (LLO) command is not sent; pressing the [LOCAL] key will return the unit to local.

Note: The lockout mode is not related to whether control is local or remote, only whether control can be returned to local by the local key.

Lockout mode (local-with-lockout and remote-with-lockout versus local and remote) is controlled by the controller. Sending the Local Lockout command (LLO) selects the local-with-lockout and remote-with-lockout pair versus remote and local without lockout. Lockout can only be canceled by the controller placing the remote enable line false, or the interface cable is disconnected.

3.2.4.2 POLLING COMMANDS

The IEEE standard provides two methods of determining the status of the devices in the system; namely serial poll and parallel poll. The parallel poll produces up to 8 bits of status from up to 8 different units simultaneously. A parallel poll is very fast but provides limited information. The serial poll provides 7 bits of status from one unit at a time.

PARALLEL POLLING

The Model 6620 provides for software parallel poll configuration. This allows for assignment of a specific bit and its "true" state for response to a parallel poll. This bit is "true" when an error condition exists.

Configuring needs to be done only once or anytime the software desires to change the configuration. The commands related to parallel poll are as follows:

IEEE-488 COMMAND	MNEMONIC	RESULT
Configure	PPC	Places unit into a state where it expects parallel poll enable and disable commands to establish which bit should be set or selected in response to a parallel poll.
Unconfigure	PPU	Removes unit from PPC state (UNL does the same thing but also unlistens device).
Enable	PPE	When unit is in PPC state, it indicates which bit and which polarity the device should respond. Hex codes 60-67 selects bits 0-7 respectively to be set to 0 for a true error response. Since logic 0 is HI on open collector lines, this provides a logical "OR" of all units designated to respond with given line. Hex codes 68-6F selects bits 0-7 respectively to be set to 1 for a true (error) response. This can provide logical NAND of all units designated to respond with a given line.
Disable	PPD	Clears any configuration previously entered. This is valid only when unit is in PPC state.

SERVICE REQUEST AND SERIAL POLLING

The Model 6620 has complete serial poll capabilities. When a serial poll is conducted, a "BYTE" of data is sent. Bits 0-3 indicate the type of error.

The following chart indicates the error types:

B7 - B0	HEX	ERROR TYPE
0000 0000	00	No error
0000 0001	01	Signal Channel under range (<.01V)
0000 0010	02	Signal Channel over range (>320V)
0000 0100	04	Reference Channel under range (<.01V)
0000 1000	08	Reference Channel over range (>320V)

3.2.4.3 UNILINE MESSAGES

IEEE-488 COMMAND	MNEMONIC	RESULT
End	END	Sent with last byte of data. A line of data may either be terminated by a line feed character or by this command.
Identify	IDY	This command, issued by the controller, causes a parallel response which was previously configured by the PPC, PPD, PPE and PPU commands.
Remote enable	REN	When true, allows the Model 6620 to respond to remote messages. When this line goes false, the unit will go to local-with-lockout state, activating the front panel.
Interface clear	IFC	Un-addresses all units and clears all special states.

3.3 RS-232C INTERFACE

3.3.1 INTRODUCTION

The Electronic Industries Association (EIA) RS-232C Interface Standard describes an accepted method of communicating over a serial data link. The functional and mechanical interface is further outlined in RS-449. Implementation of these standards varies in practice. The RS-232C interface option for the Model 6620 was designed to be compatible with most computer equipment. The information provided describes a typical interface. The proper implementation for some computers may vary.

3.3.2 THE CABLE

RS-232C communication can be achieved with a four-wire cable shown in Figure 3.3, on page 3-7. This method does not provide a hardware handshake. It does allow the user to implement the XON/XOFF protocol.

If a hardware handshake is required, a six-wire cable is necessary as shown in Figure 3.4, on page 3-8. The Model 6620 will turn off it's DTR line when the input buffer is full. This hardware handshake is particularly useful when the host computer employs buffered output and can delay transmission when DSR goes false. Hardware handshake can also be used by the host computer when its' input buffer is full to delay data being transmitted from the Model 6620.

The XON/XOFF protocol may also be used over the six-wire cable.

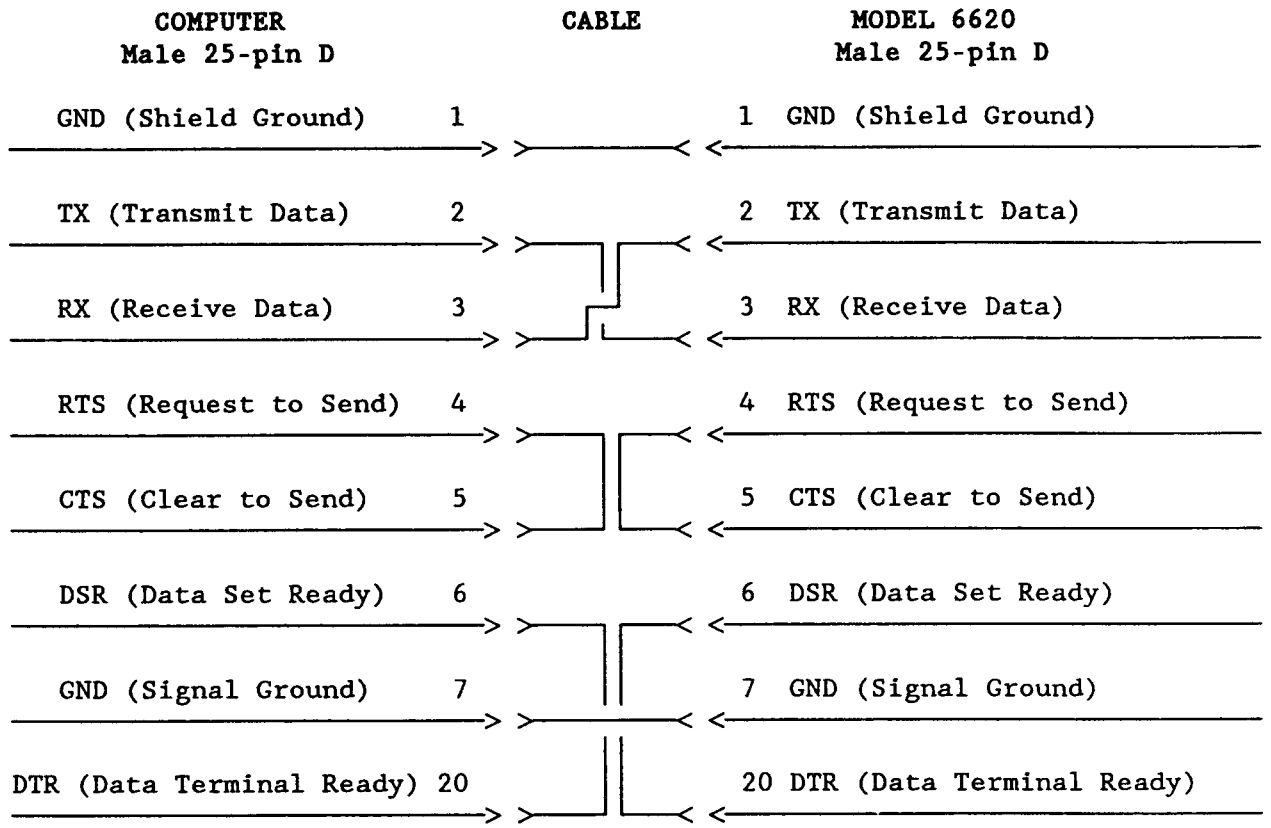

Figure 3.3 A four-wire cable

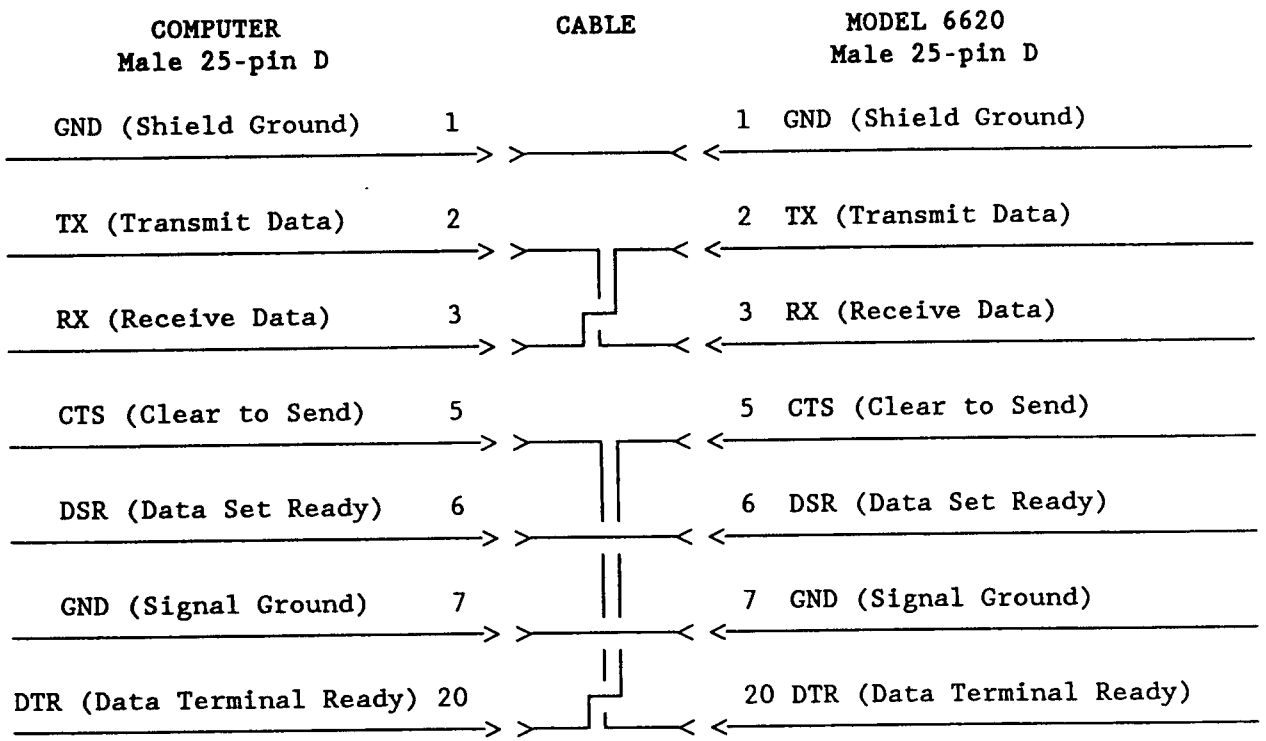

Figure 3.4 A Six Wire Cable

3.3.3 COMMUNICATION PARAMETER SELECTION PROCEDURE

The Model 6620 will act on commands sent over the serial interface. If the XON/XOFF protocol and/or the hardware handshake is employed no commands will be missed. If neither of these methods are used, the user is advised to send each command separately to the instrument. Illegal commands are ignored.

As soon as communication is established, the REMOTE LED will light on the front panel. When the REMOTE LED is on, the phasemeter will no longer respond to the front panel. Front panel operation can be resumed by pressing the [LOCAL] key.

When the unit is in [LOCAL] mode, the [LOCAL] key is used to select a number of communication parameters. When the [LOCAL] key is first pressed momentarily, the baud rate (Menu 1) will appear on the DISPLAY. Pressing the [METER RANGE] and [REL PHASE] keys will increase or decrease respectively the seven available baud rates which vary from 300 to 9600 bits/second (see Figure 3.5).

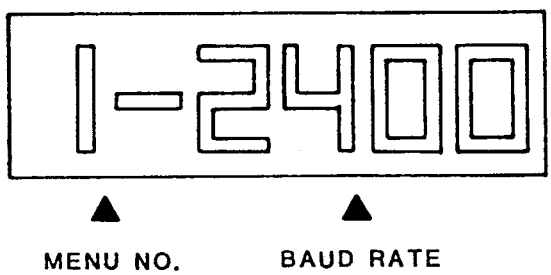

Figure 3.5 Baud Rate

Pressing the [LOCAL] key again momentarily, will display the line termination (Menu 2). The desired termination, shown in Figure 3.6, is obtained by pressing the [METER RANGE] and [REL PHASE] keys. While the Model 6620 ignores line termination as input, some computers may not.

Choices	Description
Cr	Carriage Return
LF	Line Feed
CrLF	Carriage Return/Line Feed
LFCr	Line Feed/Carriage Return
nOnE	No Termination

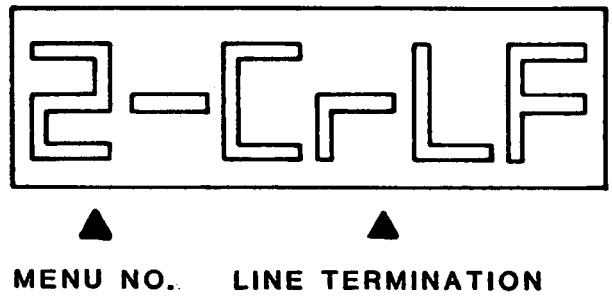

Figure 3.6 Line Termination

Three parameters are chosen in Menu 3. The first character in the display represents the number of DATA BITS. The second character selects (E)ven, (O)dd or (N)o PARITY. The last character selects the number of STOP BITS (see Figure 3.7).

Choices	Data Bits	Parity	Stop Bits
8n2	8	none	2
8n1	8	none	1
7n2	7	none	2
702	7	odd	2
7E2	7	even	2
7n1	7	none	1
701	7	odd	1
7E1	7	even	1

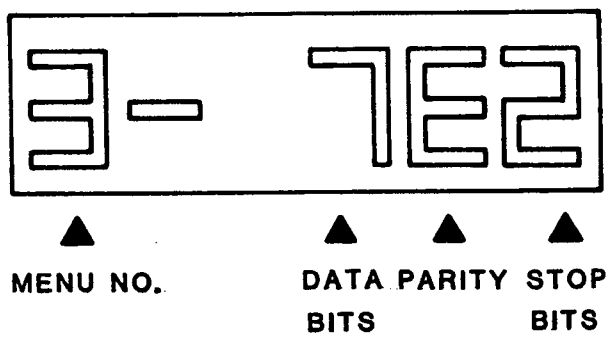

Figure 3.7 Parameter

Menu 4 determines if the XON/XOFF protocol will be used. Pressing the [LOCAL] key when Menu 4 is displayed, returns the instrument to normal operation (see Figure 3.8).

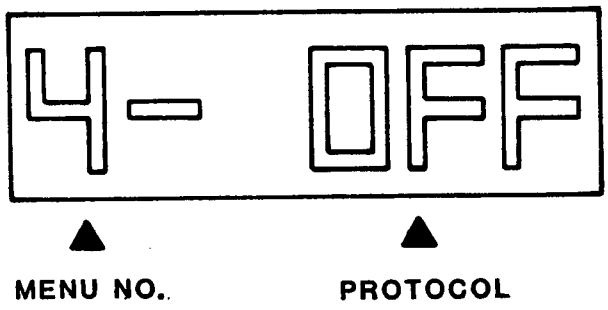

Figure 3.8 XON/XOFF Protocol

The communication parameters are stored in non-volatile ram and will be selected each time the phasemeter is turned on.

3.3.4 RS-232C DATA TRANSFER

RECEIVE COMMANDS

The Model 6620 can receive commands at any time. The command is executed immediately upon receipt. This means that no line termination character(s) is needed, however, one may be sent if desired.

The following chart indicates the ASCII characters that must be received to operate the various controls.

ASCII CODE	CONTROL FUNCTION
M1	AUTO RANGE MODE
M2	360° RANGE MODE (NON-AUTO)
M3	180° RANGE MODE (NON-AUTO)
P0	NON-RELATIVE PHASE MODE
P1	RELATIVE PHASE MODE
R1	REFERENCE CHANNEL = SINE WAVE
R2	REFERENCE CHANNEL = SQUARE WAVE
S1	SIGNAL CHANNEL = SINE WAVE
S2	SIGNAL CHANNEL = SQUARE WAVE
T0	NO LINE TERMINATION
T1	LINE TERMINATION = <CR>
T2	LINE TERMINATION = <LF>
T3	LINE TERMINATION = <CR><LF>
T4	LINE TERMINATION = <LF><CR>

ASCII CODE	CONTROL FUNCTION
C1	MANUAL 0° CALIBRATION
C2	MANUAL 180° CALIBRATION
C3	MANUAL 360° CALIBRATION
C4	AUTO CAL
Q1	QUERY PHASE ANGLE
Q2	QUERY STATUS

SEND DATA

The Model 6620 when sending data, sends a "space" first, followed by the data and terminated with the selected line-termination-character(s). The data to be sent after a "Q1" (Query Phase Angle Command) is the front panel display. After the receipt of the "Q2" (Query Status Command) the Status is sent.

The following chart indicates the format of the STATUS data sent by the Model 6620. Position is indicated from left to right, thus, "1-Signal Channel Mode" references the MSD of the status word.

1 - SIGNAL CHANNEL MODE
- 1 = Sine Wave
- 2 = Square Wave

2 - SIGNAL CHANNEL ERROR INDICATORS
- 0 = Signal Channel Within Range (No Error)
- 1 = Signal Channel Under Range Error
- 2 = Signal Channel Overload Error

3 - REFERENCE CHANNEL MODE
- 1 = Sine Wave
- 2 = Square Wave

4 - REFERENCE CHANNEL ERROR INDICATORS
- 0 = Reference Channel Within Range (No Error)
- 1 = Reference Channel Under Range Error
- 2 = Reference Channel Overload Error

5 - PHASEMETER RANGE INDICATORS
- 1 = Manual Range Mode/360° Range
- 2 = Manual Range Mode/180° Range
- 3 = Auto Range Mode/360° Range
- 4 = Auto Range Mode/180° Range

6 - RELATIVE PHASE MODE INDICATOR
- 0 = Absolute Phase Mode
- 1 = Relative Phase Mode

7 - CALIBRATION INDICATORS
- 0 = No Calibration LED's lit
- 1 = 0° Calibration LED lit
- 2 = 180° Calibration LED lit
- 3 = 360° Calibration LED lit

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SECTION 4
INCOMING ACCEPTANCE

4.1 INTRODUCTION

The following procedure should be used to verify that the Model 6620 phasemeter is operating within specifications. These tests may be used for incoming acceptance and periodic performance checks. The procedure should be followed in sequence, with the covers in place, and the phasemeter operating for ½ hour to reach thermal equilibrium.

Before testing, follow the operation procedure in Section 2 of this manual. If not operating within specifications, refer to Section 5, Calibration, before attempting any detailed maintenance.

NOTE

As an alternate to the following procedure, a Primary Phase Angle Standard, such as the Dytronics Model 311/RT-1/717S may be used for accuracy measurements between 30Hz and 10kHz. Another alternative is the use of a Computing Counter System, such as the HP Model 5360A when used with a suitable phase shifting circuit.

4.2 REQUIRED TEST EQUIPMENT

The test equipment below is required to perform the following tests.

a. Low Distortion Oscilator: frequency range from 1Hz to 100kHz with quadrature otput. Distortion <0.01% from 10Hz to 20kHz rising to 0.1% at 100kHz. Krohn-Hite Model 4024A or equivalent.

b. RC Oscillator: frequency range from 10Hz to 10MHz with balanced output. Two Krohn-Hite Model 4300B (operating in synchronism as shown in Figure 4.1) or HP Model 654A.

c. Variable Phase Generator: adjustable phase angle from 0° to 360°. HP Model 203A or equivalent.

d. DVM: Fluke Model 8012A or equivalent.

e. Matched set of coaxial cables (BNC) of the same type and length.

4.3 PROCEDURE

4.3.1 Display Calibration

After the Model 6620 has been operating in [LOCAL] mode (see Section 3.8) for a minimum of ½ hour, with covers in place, proceed with calibration.

1. Pressing the [MAN] key in the CALIBRATE section momentarily, will light the 0° LED indicator intermittently. Adjust the screwdriver control below the LED so DISPLAY indicates 0.00°.

2. Pressing the [MAN] key momentarily again, will light the 180° LED intermittently. Adjust the screwdriver control below the 180° LED so DISPLAY indicates 180.00°.

3. Pressing the [MAN] key momentarily again, will light the 360° LED intermittently. Adjust the screwdriver control below the 360° LED so DISPLAY indicates 360.00°. When the key is momentarily pressed again, the DISPLAY will return to normal operation.

4. Pressing the [AUTO] key in the CALIBRATE section, selects the AUTO METER CORRECT (AMC) mode. The unit will cycle through and automatically calibrate the display at 0°, 180° and 360° and respective LEDs will cycle off and on. This mode will not calibrate the analog output of the unit, only the DISPLAY.

4.3.2 Low Frequency Sinewave Check

Connect the output of the low-distortion oscillator, with matched cables (same type and length), to <u>both</u> the REFERENCE and SIGNAL inputs. Set both waveform selectors of the phasemeter to the sinewave mode, the oscillator frequency to 100Hz and its amplitude to 0.5Vrms. Set the phasemeter to the ±180° meter range. The DISPLAY should indicate 0.00° ±0.05°. Set the phasemeter to the 0-360° meter range. The DISPLAY should indicate 0.00° ±0.05°. Press the key in the CALIBRATE section until the 360° LED lights intermittently. Wait for a few seconds for the DISPLAY to stabilize and then press the key momentarily to return the phasemeter to normal operation. The DISPLAY should indicate 360.00° ±0.05°. Repeat this procedure at 10Hz, 1kHz, 10kHz and 50kHz, and oscillator amplitudes of 1.5V and 5Vrms.

4.3.3 High Frequency Sinewave Check

Connect the output of the RC oscillator, with matched cables to <u>both</u> inputs. Set the oscillator frequency to 100kHz and its amplitude to 0.5Vrms. Set the phasemeter to the ±180° meter range. The DISPLAY should indicate 0.00° ±0.35°. Set the phasemeter to the 0-360° meter range. The DISPLAY should indicate 0.00° ±0.35°. Press the key in the CALIBRATE section until the 360° LED lights intermittently. Wait a few seconds for the DISPLAY to stabilize and then press the key momentarily to return the phasemeter to normal operation. The display should indicate 360.00° ±0.35°. The same specifications apply when the above procedure is repeated at an amplitude of 1.5Vrms. Repeat the above procedure at 500kHz, and 1MHz. The DISPLAY tolerance should be ±2° at 500kHz and ±4° at 1MHz.

4.3.4 Quadrature Low Frequency Sinewave Check

Connect the output of the low distortion oscillator to the REFERENCE input and the quadrature output to the SIGNAL input. Set the meter range of the phasemeter to 0-360°, the oscillator to 100Hz and the amplitude of both outputs to 0.5Vrms. Record the phase reading.

Reverse the inputs and record the phase readings. The sum of both readings should be 360° ±0.10°. The tolerance of this sum is twice the specified accuracy of 0.05°. Repeat this procedure at 1kHz, 10kHz and 50kHz.

Set the meter range of the phasemeter to ±180° and repeat the above procedure. The sum of both readings should be ±0.05°.

4.3.5 Balanced High Frequency Sinewave Check

Connect the output of one RC oscillator to the REFERENCE input of the phasemeter and the output of another RC oscillator to the SIGNAL input. Balanced output, as shown in Figure 4.1, is obtained by synchronizing the two oscillators. Set the meter range of the phasemeter to 0-360, both oscillators to 100kHz and their amplitudes to 0.5Vrms. Fine tune one oscillator, by monitoring both oscillators on a suitable scope, to obtain balanced output. Record the phase reading.

Reverse the two inputs and record the phase reading. The sum of both readings should be 360.00° ±0.7°. The tolerance of this sum is twice the specified accuracy of 0.35°. Repeat this procedure at 500kHz and 1MHz. Tolerance of the total reading is ±3.5° at 500kHz and ±7° at 1MHz.

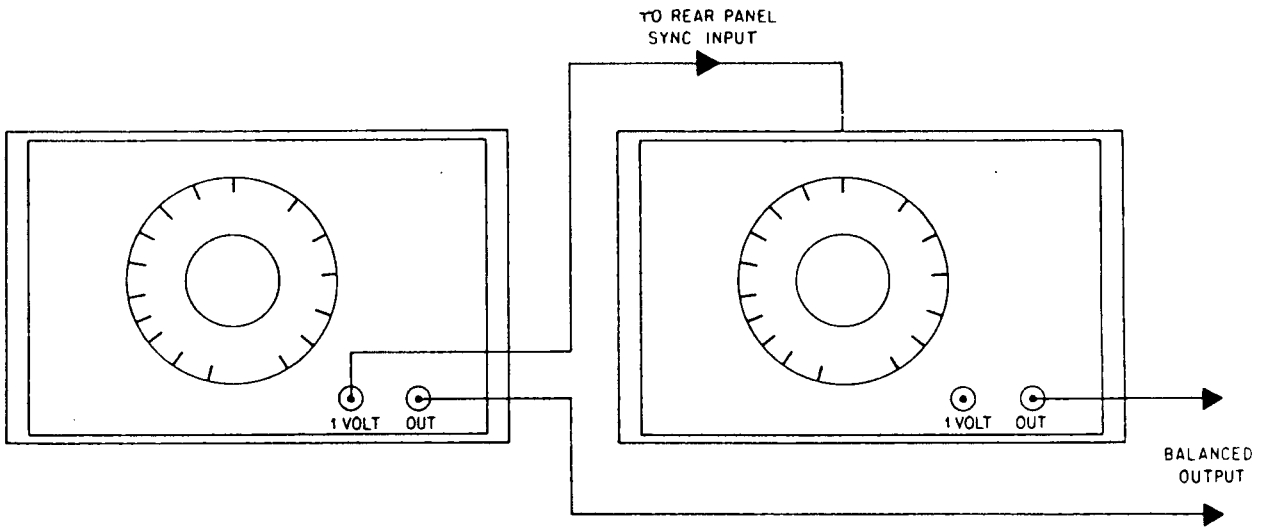

Figure 4.1 Synchronized RC Oscillators

4.3.6 Balanced Low Frequency Squarewave Check

Connect two RC oscillators as in 4.3.5. Set both oscillators to the square wave mode, frequency to 100Hz and amplitude to 1.5Vrms. Fine tune one oscillator, by monitoring both oscillators on a suitable scope, to obtain balanced output. Record the phase reading.

Reverse the two inputs and record the phase reading. The sum of both readings should be 360° ±0.2°. The tolerance of this sum is twice the specified accuracy of 0.1°. Repeat this procedure at 10Hz, 1kHz, 10kHz and 50kHz. Tolerance for the sum of these frequencies is also 360° ±0.2°.

4.3.7 Balanced High Frequency Squarewave Check

Connect two RC oscillators as in 4.3.5. Set both RC oscillators to square wave mode at a frequency of 100kHz and their amplitudes to 1.5Vrms. Fine tune one oscillator, by monitoring both oscillators on a suitable scope, to obtain balanced output. Record the phase reading.

Reverse the two inputs and record the phase readings. The sum of both readings should be 360.00° ±1.4°. The tolerance of this sum is twice the specified accuracy of 0.7°. Repeat this procedure at 500kHz and 1MHz. Tolerance of the total reading is ±7° at 500kHz and ±14° at 1MHz.

4.3.8 Analog Output Check

Connect the sinewave outputs of a variable phase generator, or two Krohn-Hite Model 4300B oscillators operating in synchronism, to the phasemeter inputs. Set both oscillators or variable phase generator to 1kHz at 1Vrms. Connect the DVM in the DC mode to the rear panel analog output connector. Set the variable phase generator for 180° or adjust one of the Model 4300B oscillators to obtain 180° phase shift, as shown on the DISPLAY of the phasemeter. The DVM should indicate 1.8Vdc. When the oscillators or generator are set to 170°, as shown on the phasemeter, the analog output should drop to 1.7Vdc or 10mV/degree. This will apply to any phase angle between 0° and 360°.

4.3.9 Relative Phase Check

If the phasemeter is set to the RELATIVE PHASE mode, the DISPLAY should switch from its initial phase to 000.00° and permit phase deviation measurements relative to its initial phase. When returned to the normal mode, the DISPLAY should indicate the original phase.

SECTION 5
CALIBRATION

5.1 INTRODUCTION

The following calibration procedure should be performed by qualified personnel only. It is strongly recommended that extra precautions be taken when working with exposed circuitry, and that insulated probes and tools be used.

CAUTION

Shut the power switch off and disconnect the line cord from the power source before repairing or replacing components.

The following procedure is provided for the calibration and adjustment of the Model 6620. Adherence to this procedure should restore the phasemeter to its original performance specifications. If the phasemeter can not be calibrated by the procedure given, see Section 5, Maintenance, or contact the factory Service Department. The location of all test points and adjustable components may be found in the component layout drawings at the rear of this manual.

5.2 REQUIRED TEST EQUIPMENT

The following equipment is required to calibrate the Model 6620 properly:

1. DIGITAL VOLTMETER, 2000 count minimum, true RMS (Fluke 8012A or equivalent).
2. LOW DISTORTION (LD) OSCILLATOR , 5Hz to 50kHz, 90° Output, 10Vrms, <0.01% Distortion (Krohn-Hite Model 4024A or equivalent).
3. HIGH FREQUENCY (HF) OSCILLATOR, 100kHz to 10MHz, 10Vrms (Krohn-Hite Model 4300B or equivalent).
4. TEST JUMPERS, 3"-6" jumpers with clips.
5. DC VOLTAGE STANDARD, 4.0000V minimum (Analogic AN3100 or equivalent).
6. 180 ±1 degree phase source, Sinewave, low distortion (<.05%).
7. 10dB 50 ohm Step Attenuators, TEXSCAN Model LA-51 or equivalent.
8. 6dB 50 ohm Fixed Attenuator.
9. Two 10dB 50 ohm Fixed Attenuators.
10. Two sets of two matched 3 foot 50 ohm Cables.
11. Two 50 ohm feed-thru terminators.
12. "T" connector.
13. Female to female coupler.

5.3 TEST PROCEDURE

5.3.1 Power Supply

Connect DMM VOLT-OHM lead to TP -15.
Set DMM to 20V range.
Check for DMM reading of -15.0V ±0.2V.
Adjust R1055 only if needed.

Connect DMM VOLT-OHM lead to TP +15.
Check for DMM reading of +15.0V ±0.2V.
Adjust R1053 only if needed.

Connect DMM VOLT-OHM lead to TP +5.
Check for DMM reading of +5.0V ±0.25V.

5.3.2 A-D Converter and Output Circuit

WARNING

DO NOT USE THE STANDARD'S CHASSIS GROUND STRAP

Set the VOLTAGE STANDARD to 3.6000V & 0 polarity
Connect the VOLTAGE STANDARD's ground to the ANALOG OUTPUT ground.
Connect the DMM COMMON lead to the VOLTAGE STANDARD's output.
Connect the DMM VOLT-OHM lead to the ANALOG OUTPUT.
Set the DMM to it's 200mV range.
Set the LD Oscillator to 100Hz, 0.5V.
Connect the LD OSCILLATOR's 200 ohm output to both phasemeter's input, using a "T" connector and matched cables.

Depress MANUAL CALIBRATE button once so that the "0" CAL. LED is flashing.
Adjust 0 CALIBRATE (front panel) for DMM reading of 0.0 ±0.1mv.
Adjust R1023 (power board) for DISPLAY reading of 0.00.

FOR LOW BAND UNITS ONLY

Set LD Oscillator to 5Hz.
Adjust R710 for DISPLAY reading of 0.00.
Set LD Oscillator to 100Hz.

Depress MANUAL CALIBRATE button twice so that the "360" CAL. LED is flashing. Set VOLTAGE STANDARD to + polarity.

Adjust 360 CALIBRATE (front panel) for DMM reading of 0.0 ±0.1mV.
Adjust R1030 (power board) for DISPLAY reading of 360.00.

Depress MANUAL CALIBRATE button three times so that the "180" CAL. LED is flashing.

Set VOLTAGE STANDARD to 1.8000V -polarity.
Adjust 180 CALIBRATE (front panel) for DMM reading of 0.0 ±0.1mV.
Check for DISPLAY reading of -180.00 ±0.01.

5.3.3 DC Offset Adjustments

Connect jumpers from TP108 & TP408 to ground.
Disconnect LD Oscillator from both phasemeter inputs.
Depress MANUAL CALIBRATE button twice so that no CAL. LED is flashing.
Set both WAVEFORM select switches to squarewave.

Connect DMM VOLT-OHM lead to TP350.
Adjust R332 for DMM reading of 0.0 ±0.5mV.

Connect DMM VOLT-OHM lead to TP469.
Adjust R454 for DMM reading of 0.0 ±5mV.

Connect DMM VOLT-OHM lead to TP50.
Adjust R32 for DMM reading of 0.0 ±0.5mV.

Connect DMM VOLT-OHM lead to TP169.
Adjust R154 for DMM reading of 0.0 ±5mV.

5.3.4 Level Detector Adjustments

Connect HF Oscillator main output to both phasemeter inputs.
Set HF Oscillator to 100Hz,Sinewave.
Connect AC VOLTMETER to HF Oscillator main output.
Set AC VOLTMETER to 2.0V AC range.
Set DMM to 20V DC range.

Connect DMM VOLT-OHM lead to TP64.
Adjust HF Oscillator for AC VOLTMETER reading of approximately 0.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.297V.
Check for DMM reading of more negative than -8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.304V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R67 as needed.

Adjust HF Oscillator for AC VOLTMETER reading of approximately 1.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.06V.
Check for DMM reading of more positive than +8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.04V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R89 as needed.

Connect DMM VOLT-OHM lead to TP364.
Adjust HF Oscillator for AC VOLTMETER reading of approximately 0.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.297V.
Check for DMM reading of more negative than -8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.304V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R367 as needed.

Adjust HF Oscillator for AC VOLTMETER reading of approximately 1.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.06V.
Check for DMM reading of more positive than +8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.04V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R389 as needed.

Set HF Oscillator to 3.0MHz,Sinewave.
Connect DMM VOLT-OHM lead to TP64.
Adjust HF Oscillator for AC VOLTMETER reading of approximately 0.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.297V.
Check for DMM reading of more negative than -8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.304V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R71 as needed.

Connect DMM VOLT-OHM lead to TP364.
Adjust HF Oscillator for AC VOLTMETER reading of approximately 0.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.297V.
Check for DMM reading of more negative than -8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.304V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R371 as needed.

Set HF Oscillator to 100Hz,Squarewave.
Set both PHASEMETER waveform selectors to squarewave.
Connect DMM VOLT-OHM lead to TP64.
Adjust HF Oscillator for AC VOLTMETER reading of approximately 0.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.297V.
Check for DMM reading of more negative than -8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.304V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R83 as needed.

Adjust HF Oscillator for AC VOLTMETER reading of approximately 1.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.06V.
Check for DMM reading of more positive than +8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.04V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R85 as needed.

Connect DMM VOLT-OHM lead to TP364.
Adjust HF Oscillator for AC VOLTMETER reading of approximately 0.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.297V.
Check for DMM reading of more negative than -8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 0.304V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R383 as needed.

Adjust HF Oscillator for AC VOLTMETER reading of approximately 1.2V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.06V.
Check for DMM reading of more positive than +8V.
Slowly adjust HF Oscillator for AC VOLTMETER reading of 1.04V.
Check for DMM reading of 0.0V ±0.5V.
Adjust R385 as needed.

5.3.5 Symmetry Loop Adjustment

Set LD Oscillator, main & quadrature output to 100Hz, 0.5V.
Connect main output to phasemeter REFERENCE input.
Connect quadrature output to phasemeter SIGNAL input.
Set Reference waveform selector to squarewave.
Set Signal waveform selector to sinewave.

Set METER RANGE to ±180.
Record the DISPLAY reading.

Set METER RANGE to 0-360.
Record the DISPLAY reading.

Adjust R511 for 1/2 of the difference in the two readings.

REPEAT THIS STEP UNTIL THERE IS NO DIFFERENCE

FOR LOW BAND UNITS ONLY

Set LD Oscillator ro 5Hz.
Set METER RANGE to ±180.
Record the DISPLAY reading.
Set METER RANGE to 0-360.
Record the DISPLAY reading.
Adjust R509 for 1/2 of the difference in the two readings.

REPEAT THIS STEP UNTIL THERE IS NO DIFFERENCE

Set LD Oscillator to 50kHz.
Set METER RANGE to ±180.
Record the DISPLAY reading.

Set METER RANGE to 0-360.
Record the DISPLAY reading.

Adjust C523 for 1/2 of the difference in the two readings.

REPEAT THIS STEP UNTIL THERE IS NO DIFFERENCE

5.3.6 100Hz Calibration

Set LD Oscillator, main output to 100Hz, 0.5V.
Set both phasemeter waveform selectors to sinewave.
Set METER RANGE to ±180.
Adjust R211 for DISPLAY reading of 0.00.

FOR LOW BAND UNIT ONLY

Set LD Oscillator to 5Hz.
Adjust R209 for DISPLAY reading of 0.00.
Set LD Oscillator to 100Hz.

Set METER RANGE to 0-360.
Adjust R699 for DISPLAY reading of 0.00.

Force a 360 reading by disconnecting and reconnecting the reference input.
Adjust R704 for DISPLAY reading of 360.00.

Connect the 180 degree phase source to the Phasemeter's inputs.
Set the 180 phase source to 100Hz, 0.5V.

Set the METER RANGE to 0-360.
Record the DISPLAY reading.
Set the METER RANGE to ±180.
Adjust R706 for the same DISPLAY reading.

REPEAT UNTIL NO CHANGE

5.3.7 50kHz Calibration vs. Amplitude

Set LD Oscillator 200 ohm output to 50kHz, 9.9V.
Set LD Oscillator quadrature output to 0.5V.
Connect the 200 ohm output to the STEP ATTENUATOR through a 6 dB FIXED ATTENUATOR.
Connect a 50 ohm terminator to the STEP ATTENUATOR's output.

The ATTENUATOR box must be terminated with a 50 ohm terminator.

Connect the quadrature output to the SIGNAL input.
Connect the STEP ATTENUATOR's output to the REFERENCE input.
Set the STEP ATTENUATOR to 0 dB.
Record the DISPLAY reading.
Set the STEP ATTENUATOR to 10 dB.
Adjust C147 for same DISPLAY reading.

Over adjust BY 100% and repeat until no change in DISPLAY reading.

Connect the quadrature output to the REFERENCE input.
Connect the STEP ATTENUATOR's output to the SIGNAL input.
Set the ATTENUATOR box to 0 dB.
Record the DISPLAY reading.
Set the STEP ATTENUATOR to 10 dB.
Adjust C447 for same DISPLAY reading.

Over adjust BY 100% and repeat until no change in DISPLAY reading.

5.3.8 50kHz & 500kHz Calibration (less than 1.0V)

Connect the STEP ATTENUATOR's output to both phasemeter's inputs.
Set the STEP ATTENUATOR to 0dB.
Set LD Oscillator to 50 kHz, 8.0V.
Connect test jumper from TP150 to TP450.
Check for DISPLAY reading 0.00 ±0.05.

Only if out of tolerance trim as follows:
If reading is +, increase C174 by 0.5pF per 0.10 degrees.
If reading is −, increase C474 by 0.5pF per 0.10 degrees.

CAUTION

NEVER EXCEED 3.3pF
TRIMMING HAS NO AFFECT UNTIL STEP 5.3.7 IS REPEATED
REPEAT THIS STEP AFTER REPEATING STEP 5.3.7

Set HF Oscillator to 500kHz, 0.8V, SINEWAVE.
Connect HF Oscillator main output to both phasemeter inputs.
Adjust C223 for DISPLAY reading of 0.00 ±0.50.

REMOVE ALL JUMPERS

Connect the HF Oscillator through the "T" connector and one 10dB FIXED AT TENUATOR to the STEP ATTENUATOR.
Connect a 50 ohm terminator to the STEP ATTENUATOR's output.
Connect the other half of the "T" connector to 6dB FIXED ATTENUATOR through the second 10dB FIXED ATTENUATOR.
Connect a 50 ohm terminator to the 6dB FIXED ATTENUATOR's output.
Connect the SIGNAL input to the STEP ATTENUATOR's output.
Connect the REFERENCE input to the FIXED ATTENUATOR's output using the fe male to female coupler.
Set the HF Oscillator to 50kHz, 8.0V.

Set the ATTENUATOR box to 0 dB.
Adjust C345 for DISPLAY reading of 0.00.

Set the ATTENUATOR box to 10 dB.
Adjust C339 for DISPLAY reading of 0.00.

Set the ATTENUATOR box to 20 dB.
Adjust C347 for DISPLAY reading of 0.00.

Set the ATTENUATOR box to 30 dB.
Check for DISPLAY reading of 0.00 ±0.25.

Connect the REFERENCE input to the STEP ATTENUATOR's output.
Connect the SIGNAL input to the 6dB FIXED ATTENUATOR's output using the female to female coupler.

Set the ATTENUATOR box to 0 dB.
Check for DISPLAY reading of 0.00 ±.02.

Set the ATTENUATOR box to 10 dB.
Adjust C39 for DISPLAY reading of 0.00.

Set the ATTENUATOR box to 20 dB.
Adjust C47 for DISPLAY reading of 0.00.

Set the ATTENUATOR box to 30 dB.
Check for DISPLAY reading of 0.00 ±0.25.

5.3.9 Attenuator Adjustments (1.0V - 10V)

Connect the LD Oscillator 200 ohm output to both phasemeter inputs.
Set LD Oscillator to 100Hz, 1.5V.
Connect jumper from TP408 to ground.

Set LD Oscillator to 0.8V.
Connect jumper from TP108 to ground.

Set LD Oscillator to 10.0kHz 1.0V.
Adjust C307 for DISPLAY reading of 0.00.

Set LD Oscillator to 50.0kHz.
Adjust R304 for DISPLAY reading of 0.00.

Set LD Oscillator to 5.0kHz.
Adjust C305 for DISPLAY reading of 0.00.

REPEAT UNTIL ALL THREE ADJUSTMENTS ARE CORRECT.
REMOVE JUMPERS.

Set LD Oscillator to 100Hz, 1.5V.
Connect jumper from TP108 to ground.

Set LD Oscillator to 0.8V.
Connect jumper from TP408 to ground.

Set LD Oscillator to 10.0kHz, 1.0V.
Adjust C7 for DISPLAY reading of 0.00.

Set LD Oscillator to 50.0kHz.
Adjust R4 for DISPLAY reading of 0.00.

Set LD Oscillator to 5.0kHz.
Adjust C5 for DISPLAY reading of 0.00.

REPEAT UNTIL ALL THREE ADJUSTMENTS ARE CORRECT.
REMOVE JUMPERS.

5.3.10 Attenuator Adjustments (10V - 100V)

Set LD Oscillator to 100Hz, 5.0V.
Connect jumper from TP408 to ground.
Disconnect LD Oscillator from REFERENCE input.
Set LD Oscillator to 100Hz, 10V.
Wait for <.01 LED to light.
Connect LD Oscillator to REFERENCE input.
Wit approximately 10 seconds.
Connect jumper from TP108 to ground.
Check TP50 for 0.6V AC ±0.1V.

Set LD Oscillator to 10.0kHz.
Adjust C19 for DISPLAY reading of 0.00.

Set LD Oscillator to 50.0kHz.
Adjust R15 for DISPLAY reading of 0.00.

Set LD Oscillator to 5.0kHz.
Adjust C17 for DISPLAY reading of 0.00.

REPEAT UNTIL ALL THREE ADJUSTMENTS ARE CORRECT.
REMOVE JUMPERS.

Set LD Oscillator to 100Hz, 5.0V.
Connect jumper from TP108 to ground.
Disconnect LD Oscillator from SIGNAL input.
Set LD Oscillator to 100Hz, 10V.
Wait for <.01 LED to light.
Connect LD Oscillator to SIGNAL input.
Wit approximately 10 seconds.
Connect jumper from TP408 to ground.
Check TP350 for 0.6V AC ±0.1V.

Set LD Oscillator to 10.0kHz.
Adjust C319 for DISPLAY reading of 0.00.

Set LD Oscillator to 50.0kHz.
Adjust R315 for DISPLAY reading of 0.00.

Set LD Oscillator to 5.0kHz.
Adjust C317 for DISPLAY reading of 0.00.

REPEAT UNTIL ALL THREE ADJUSTMENTS ARE CORRECT.
REMOVE JUMPERS.

END OF CALIBRATION PROCEDURE

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SECTION 6
CIRCUIT DESCRIPTION

6.1 INTRODUCTION

A simplified block diagram of the Model 6620 is shown in figure 6.1. The phasemeter consists of two signal conditioning channels and a phase-to-digital converter. The signal conditioning is performed by an attenuator with auto-range circuits, two amplifier stages, two comparator circuits and a symmetry control loop. The phase-to-digital converter consists of a pulse generator with pulse width proportional to phase, a converter that generates a voltage proportional to pulse width, and an analog-to-digital converter. Complete schematics are in Section 8 of this manual.

NOTE

Since the signal conditioning channels described in Section 6.2 through 6.5 are identical, only the REFERENCE channel will be described.

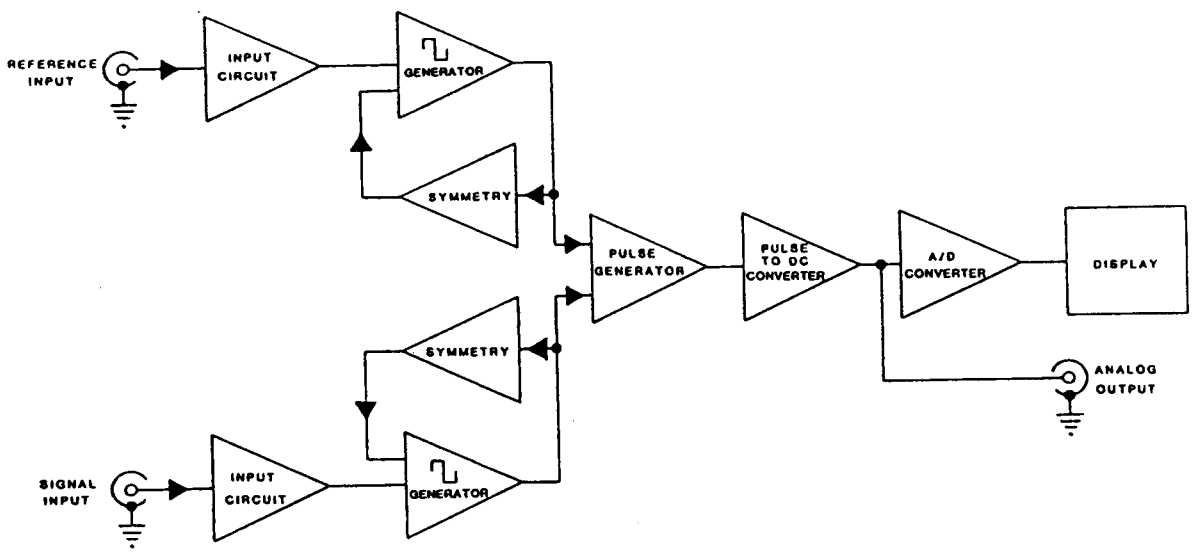

Figure 6.1 Model 6620 Simplified block diagram

6.2 INPUT CIRCUIT

The Input Circuit shown in Figure 6.2 converts the input signal which can vary from 10mV to 320V to an amplitude between 0.6V and 2.0V. This is accomplished by selecting the appropriate input attenuator and gain setting of the input amplifier.

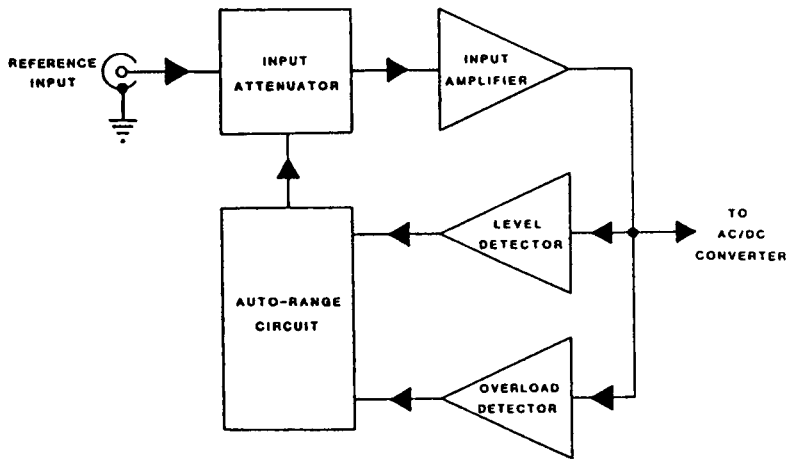

Figure 6.2 Input Circuit Simplified Block Diagram

6.2.1 INPUT ATTENUATOR

As shown in Figure 6.3, there are two attenuators and a bypass relay. When the input amplitude is under 1.0Vrms the bypass relay K128 is activated. In this mode, the tungsten lamp DS1, CR21 and CR26 provide overload protection. The first attenuator is used for input amplitudes of between 1V and 10Vrms. This attenuator which is a simple voltage divider with broad-banding networks, is activated by relays K126 and K127. The second attenuator is used for amplitudes above 10.0Vrms with a secondary tap for signals exceeding 100Vrms. Relays K124 and K125 are used for the range of 10V to 100Vrms and for amplitudes above 100V relays K124 and K123 are activated.

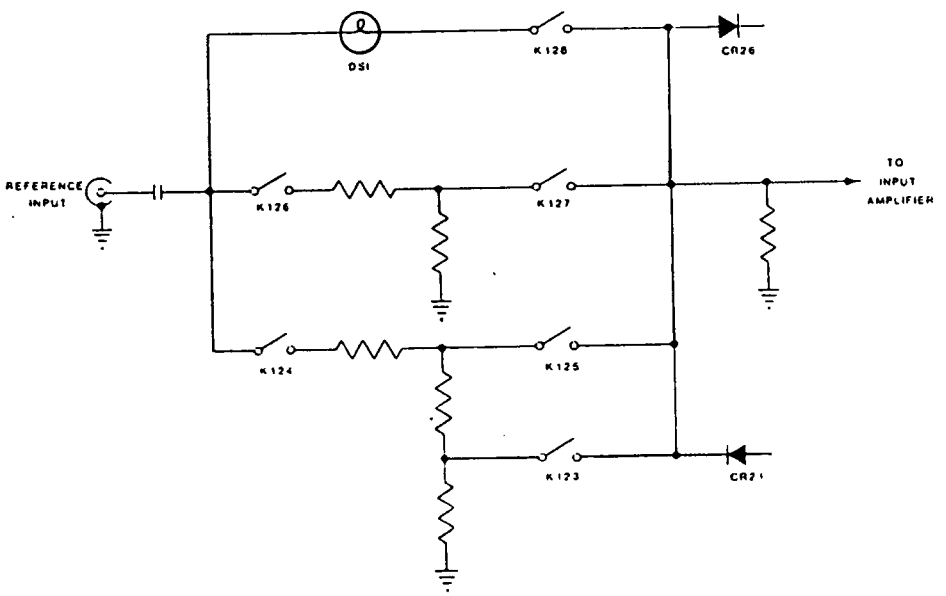

Figure 6.3 Input Attenuator Simplified Block Diagram

6.2.2 INPUT AMPLIFIER

The Input Amplifier, shown in Figure 6.4, has a high impedance differential input stage, Q30 and Q31. High gain is supplied by the second stage, Q47 and Q48, and the output stage, Q51 and Q53. The gain is varied in magnitudes of 2, 6.3, 20 and 63, and is controlled by the auto range circuit operating relays K129 and K130.

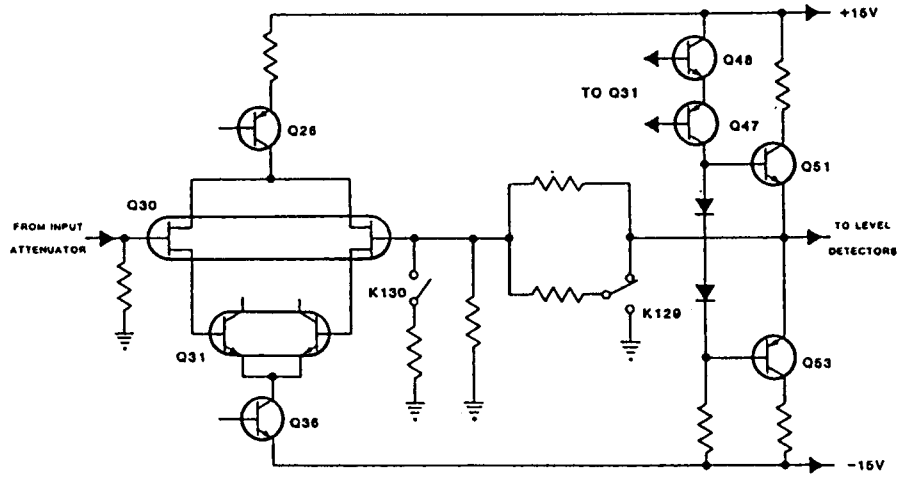

Figure 6.4 Input Amplifier Simplified Block Diagram

6.2.3 INPUT LEVEL DETECTOR

The Input Level detector has two main sections, the ac-dc converter and the detector. The converter is composed mainly of U73, Q76, CR76 and C76 while the detector consists of U76, CR87,CR88 and associated components. The converter first offsets the input amplifier's output signal so it is negative going with it's positive peak at approximately zero volts. This signal is then rectified by CR76 which produces a negative voltage on C76 that is proportional to the peak-to-peak amplitude. The detector then compares this voltage to pre-defined level and signals any out of range conditions. The output of U76 is normally 0 ±0.5Vdc, but at higher than normal amplitude the output will momentarily be more positive than +10V and return to 0 ±0.5Vdc after range switching is completed. At a lower than normal signal the output is more negative momentarily than -10V and also returns to normal after range switching. Two sets of threshold are used, one for sinewave mode and the other for squarewave mode, these are controlled by Q86 and Q90.

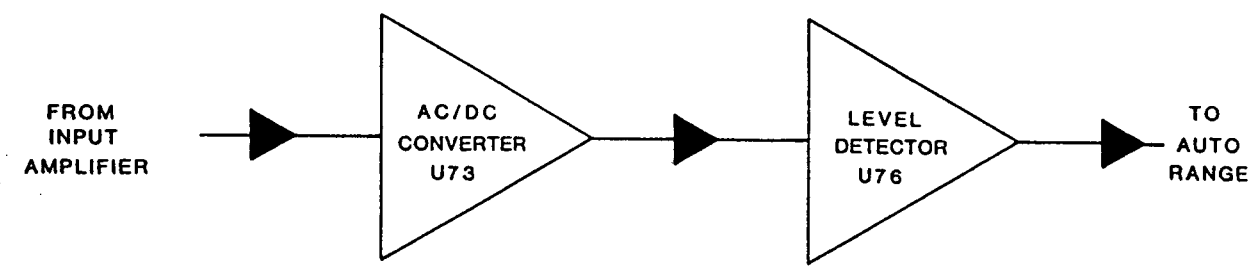

Figure 6.5 Input Level Detector Simplified Block Diagram

6.2.4 AUTO-RANGE

The Auto-Range circuit, shown in Figure 6.6, consists of a timer U108, an up-down counter U112, a decoder U119 and control logic. When the input level detector senses an out of range condition, the direction control line of the range counter is set and the timer is activated. This causes the counter to increment for a high input level or decrement for a low level. The timer then causes a delay so that the level detector can respond to the new range setting. If the level is still incorrect after the timer's delay the counter will again step in the appropriate direction, as above. This cycle will repeat until the level detector senses an "in range" condition or the maximum or minimum range is encountered. The decoder uses the range number from the counter to activate the appropriate attenuator and gain relays. An over load condition is detected by Q111 which forces the counter directly to the highest range, range 8.

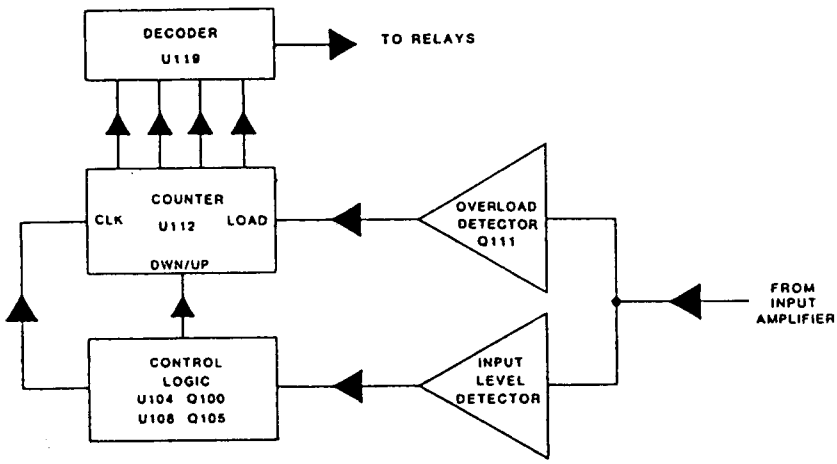

Figure 6.6 Auto-Range Simplified Block Diagram

6.3 GAIN STAGE

The Gain Stage, shown in Figure 6.7, is a wideband, operational amplifier with a gain of -20. It has a differential input stage Q153, a high gain second stage Q165 and Q167, and a low impedance output stage, Q168 and Q170. The non-linear circuit, Q146 and Q147, supplies a signal to the positive input of the amplifier which causes the overall gain to decrease to less than minus one on the peaks of the waveform to avoid overloading the output stage.

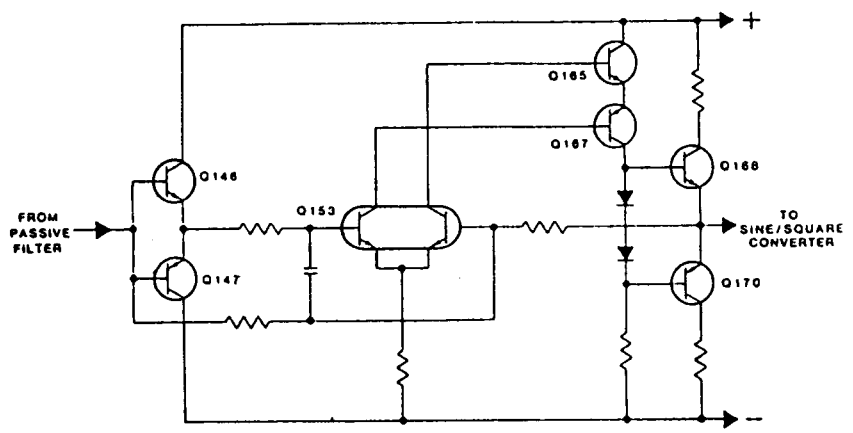

Figure 6.7 Gain Stage Simplified Block Diagram

6.4 SINEWAVE-TO-SQUAREWAVE CONVERTER

As shown in Figure 6.8, this circuit consists of two comparators. The main comparator, U187, produces the squarewave used by the symmetry correction circuit and the flip-flop. It responds to the zero crossing of it's input signal and has no hysteresis except for a slight amount of high frequency positive feedback to speed up switching and reduce effects of noise. The reset comparator, U181, produces the reset signal used by the pulse generator. Hysteresis is used in this circuit to eliminate unwanted output transitions due to noise. It is also arranged so the actual threshold is shifted away from zero so the pulse generator is reset when there is no chance of noise causing a transition on the main comparator's output. The signal channel only has an additional circuit, Q483, that allows the threshold to be shifted to the opposite polarity for the 180° range.

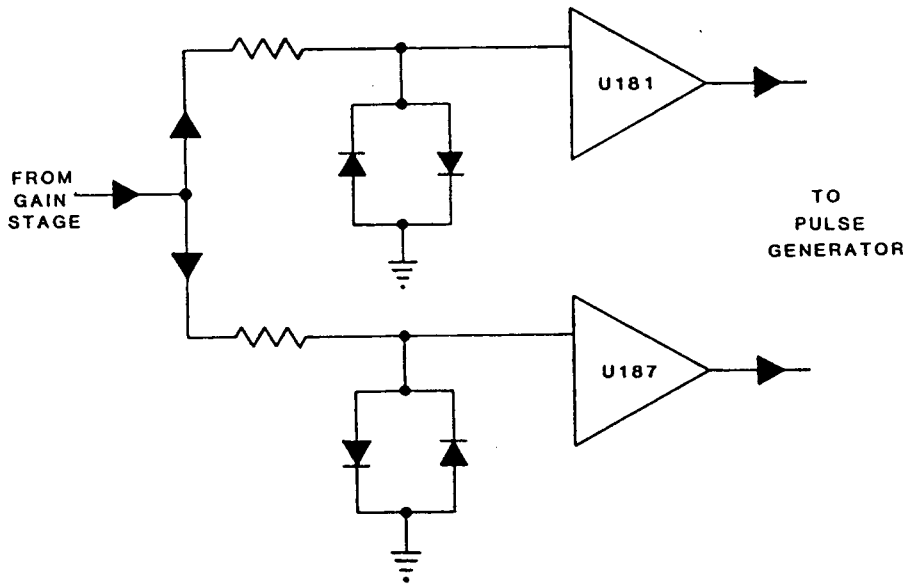

Figure 6.8 Sine/Square Converter Simplified Block Diagram

6.5 SYMMETRY CORRECTION

This circuit, shown in Figure 6.9, compensates for any dc offsets in the signal path. The compensation is done by detecting the time symmetry of the squarewave generated by the sine-to-square converter and offsetting the gain stage to keep a constant symmetry as the input amplitude and/or frequency changes. Since this correction does not work for waveform with fast rise and fall times, such as squarewaves and pulses, it can be deactivated for these waveforms.

The symmetry circuit consists of a precision symmetry detector, an integrator and a sample and hold circuit. The detector is made up of a diode bridge, U224, two stable zener diodes, VR207 and VR221, and their associated components. The squarewave signal drives the symmetry detector which produces a squarewave of precise amplitude with the same duty cycle. This signal is averaged by the integrator, U201 and Q201, so that it's output will become more negative if the duty cycle increases. The output of the integrator is sampled once each cycle by the sample and hold circuit, Q199, C196 and U196, and is applied to the gain stage to correct any changes in the symmetry.

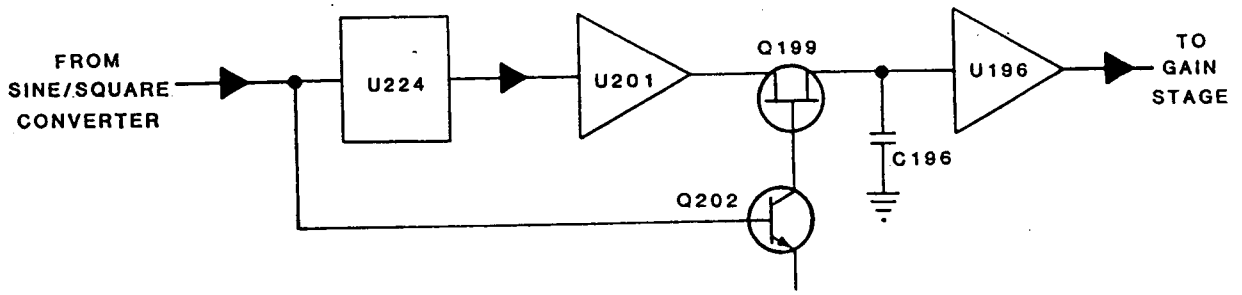

Figure 6.9 Symmetry Circuit Simplified Block Diagram

6.6 PULSE GENERATOR

As shown in Figure 6.10, the squarewave outputs of the two channels are dc level shifted and applied to the multiplexer U632, which selects between the true and inverted squarewaves. The inverted signals from the signal channel are used when in the 180° range. The rising edge of these signals trigger the pulse generator circuits, U646 and U656, to produce a very short pulse, <10nsec. Once a pulse has been generated, the circuit can not produce another until it is reset by the associated reset signal. This reset does not occur until after the opposite zero crossing of the input signal, which assures that only a single pulse is produced for each cycle of the input signal.

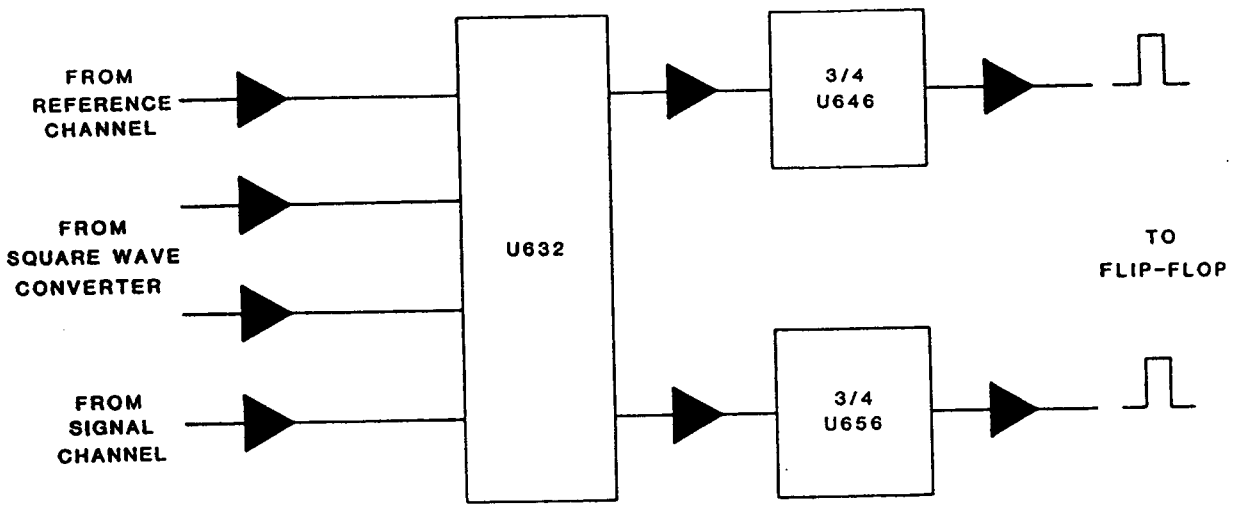

Figure 6.10 Pulse Generator Simplified Block Diagram

6.7 FLIP-FLOP

As shown in Figure 6.11, the pulse generator outputs trigger the flip-flop, U646 and U656, to produce a pulse whose duty cycle is proportional to the phase difference between the two input signals. A duty cycle of 50% is equivalent to 180° in the 360° range. In the 180° range the duty cycle of the pulse is increased by 50% with respect to the 360° range to allow for the negative readings in that range. Q665 and Q667 buffer the flip-flop outputs.

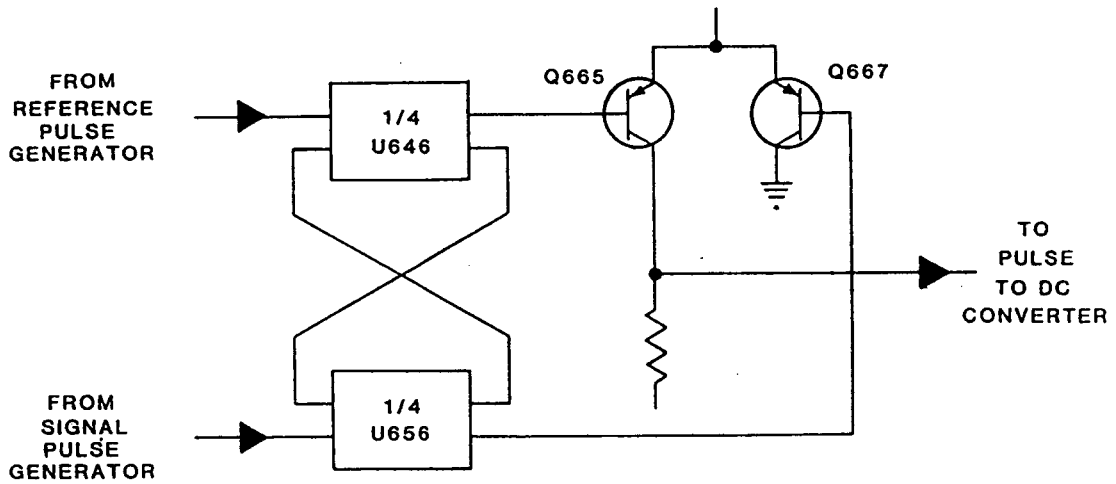

Figure 6.11 Flip-Flop Simplified Block Diagram

6.8 PULSE-TO-DC CONVERTER

The pulse-to-dc converter, as shown in Figure 6.12, consists of a stable current source that is switched by the pulsed output of the flip-flop to generate a pulsed voltage whose average dc voltage is proportional to phase. A precise current is generated in Q686 by the zener diode U683 and buffer U682. The current is then switched from diode CR690 to CR691 by the pulse output from Q665 to generate a pulsed voltage across R690. This voltage is smoothed by the filter consisting of intergrator U720 and Q720, sample-and-hold switched filter Q731 and C732, and buffer Q732, Q734 and U734.

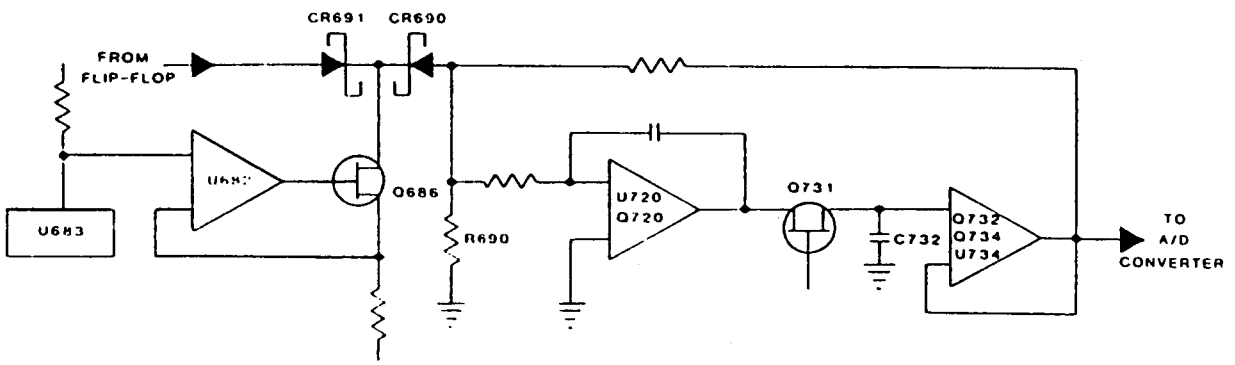

Figure 6.12 Pulse-To-DC COnverter Simplified Block Diagram

6.9 ANALOG-TO-DIGITAL CONVERTER

Analog-to-digital conversion, shown in the A/D Converter and Microprocessor schematic (Figure 8.5), is accomplished by the A/D converter U1020, which receives its clock from the counter U1037 that divides the system clock by 10 providing a 100k Hz clock rate. This clock produces a conversion time of 400msec. The converter has ±20,000 counts full scale but this is not adequate for 0.01 degree resolution on the 360° range. To obtain the required resolution the minus input is offset by 1.8000V, which allows the circuit to measure +38,000/−2000 counts. The microprocessor, U1000, then adds 18000 counts to this reading which restores the original 0-36000 count range.

6.10 FREQUENCY DETECTOR

The frequency detectors U611 and U615, shown in the phase-to-dc converter schematic (Figure 8.3), compare the input signal period to fixed time periods to determine the relative frequency. The rising edge of the input signal starts the period timers and the next rising edge stores the state of the timers. Any timer that has not reset indicates the frequency is higher than that timers threshold.

6.11 MICROPROCESSOR UNIT (MPU) INTERFACE

The MPU, as shown in the A/D Converter and Microprocessor schematic (Figure 8.5), monitors and controls the phasemeter's functions via the four input/output ports of the two parallel interface adapters, U1014 and U1015. These ports consist of eight input/output lines, plus two control lines. Two of the ports are used to determine the input range and over/under range condition of the phasemeter REFERENCE and SIGNAL input channels. These ports also control the sinewave/squarewave mode of their respective channel. A third port is the interface to the analog-to-digital converter, U1020. This port controls the A/D converter, reads its data, and monitors its over/under range flags. The fourth port controls the front panel DISPLAY and scans the keyboard for operator input.

6.12 FRONT PANEL DISPLAY AND CONTROLS

The front panel DISPLAY and indicators, shown in the DISPLAY schematic (Figure 8.6), are driven by segment driver transistors Q1100 through Q1107, and by digit select transistors Q1108 through Q1115. The DISPLAY is scanned sequentially by the decoder U1108, while segment data is applied through the latch U1100. At the same time, the condition of the keyboard can be determined by reading the feedback line from the keyboard.

SECTION 7
MAINTENANCE

7.1 INTRODUCTION

This maintenance procedure should be performed by qualified personnel only. It is strongly recommended that extra precautions be taken when working with exposed circuitry, and that insulated probes and tools be used.

> **CAUTION**
>
> TURN POWER OFF AND DISCONNECT THE LINE CORD FROM THE POWER SOURCE BEFORE REPAIRING OR REPLACING COMPONENTS.

This maintenance procedure is designed to allow a competent service technician to localize a failure within the instrument to the malfunctioning circuit. After replacing the defective component(s), it may be necessary to recalibrate either the whole instrument or at least the circuit which was affected.

7.2 REQUIRED TEST EQUIPMENT

The following equipment is required to calibrate the Model 6600 properly:

1. DIGITAL VOLTMETER, 2000 count minimum, true RMS (Fluke 8012A or equivalent).
2. LOW DISTORTION (LD) OSCILLATOR , 5Hz to 50kHz, 90° Output, 10Vrms, <0.01% Distortion (Krohn-Hite Model 4024A or equivalent).
3. OSCILLOSCOPE, Bandwidth from DC to 30MHz, vertical sensitivity 5mV/cm, AC/DC coupled (Tektronix Model 465 or equivalent).

7.3 GENERAL APPROACH

The most effective approach to trouble shooting this instrument can best be determined by reviewing Section 6, Circuit Description and understanding the instrument's operation and knowing the symptoms of the malfunction. In general if the instrument's front panel is not operating correctly, the power supplies should be checked followed by the microprocessor circuits. However, if the front panel does seem to be operating correctly but the phase reading is wrong, check the power supply followed by the analog board.

7.4 POWER SUPPLY

If a malfunction occurs in this instrument the power supplies should be checked first. There are 3 regulated supplies in this unit. Both their regulated output and their unregulated input should be checked. The following chart will assist with these measurements.

Supply	Regulated Volts(max./min.)	Unregulated Volts(max./min.)	Unreg. Ripple Volts p-p (typ.)
+15V	+15.3V/+14.7V	+21V/+17V	1.7V
-15V	-15.3V/-14.7V	-21V/-17V	1.7V
+5V	+5.3V/+4.7V	+12.5V/+7.5V	0.6V

If the supply voltages and/or unregulated supplies are found to be incorrect, the malfunction may be in either the supply or an excessive load caused by a malfunctioning circuit in the unit. One way to determine the source of the malfunction is to disconnect the analog board from the supply by unplugging J1020 and supplying external loads. Use 75 ohm loads for the 15V supplies and a 10 ohm load for the 5V supply, these loads should have a 5W power rating. If the supplies are now correct the analog board must be malfunctioning. If, however, the supplies are still incorrect then the the problem must be with the supply itself.

7.5 MICROPROCESSOR AND DISPLAY CIRCUITS

7.5.1 Front Panel Display

Malfunctions of the front panel display can be grouped into several types. One type is the failure of a single element of the display, which is fixed by replacing that particular device. A group of elements not functioning is caused by either the device that contains those elements or the driver for that group, Q1100 to Q1115.

If the entire display is blank, check U1108 pin 15 for a pulse with a period of 1ms and a duration of 125us. When no pulse is found check U1108 pin 1 for a squarewave with a 1ms period, if missing the MPU circuit should be checked otherwise U1108 is probably defective.

7.6 MAIN ANALOG CIRCUITS

Troubleshooting of the analog circuitry can be done by first localizing the malfunction to a functional block and then tracing the malfunction to it's source. The following sub-sections refer to individual functional blocks and start with a description of that block's normal input and output signals. This description is followed by more detailed information for tracking the malfunction to it's exact source.

7.6.1 Auto-Range Circuit

This circuit is working properly when the signal amplitude on TP50 is between 0.6V RMS and 2.0V RMS (1.7V - 5.7V P-P) for any valid input signal. Any other condition indicates a malfunction in this circuit or in the INPUT BUFFER.

If there is large dc voltage on TP50, greater than 0.1V, the input buffer should be checked for a malfunction.

To troubleshoot the auto-range circuit the input range should be locked so that the circuit will be stable while making measurements. This can be done by grounding TP108.

WARNING!

INPUT SIGNALS IN EXCESS OF 10V PEAK CAN DAMAGE THE INPUT CIRCUITS WHEN THE RANGE IS LOCKED!

The actual range that the unit is set to can be determined from the binary number in counter U112. The easiest way to determine this number is to measure the voltages on pins 12 thru 15 of U119. This gives a binary number when pin 15 is used as the ones bit, pin 14 is used as the twos bit, etc. The bit is considered to be a zero if it's voltage is less than 0.5V and is a one when it's voltage is greater than 3.0V.

By using this number and the chart in Figure 7.1 it can be determined if the drive circuits, the selected attenuator and the selected gain setting of the INPUT BUFFER are working correctly.

				RELAYS							
Range	Input Volts	Input Atten	Buffer Gain	K123	K124	K125	K126	K127	K128	K129	K130
0	0.010 - 0.032	1	63.2	off	off	off	off	off	on	on	on
1	0.032 - 0.100	1	20.0	off	off	off	off	off	on	on	off
2	0.100 - 0.320	1	6.3	off	off	off	off	off	on	off	on
3	0.320 - 1.000	1	2.0	off	off	off	off	off	on	off	off
4	1.0 - 3.2	10	6.3	off	off	off	on	on	off	off	on
5	3.2 - 10.0	10	2.0	off	off	off	on	on	off	off	off
6	10 - 32	100	6.3	off	on	on	off	off	off	off	on
7	32 - 100	100	2.0	off	on	on	off	off	off	off	off
8	100 - 300	1000	6.3	on	on	off	off	off	off	off	on

Figure 7.1 Model 6620 attenuator/gain relay usage chart

Any desired range can be set by the following procedure:

1. Lock the range by grounding TP 108.
2. Set the input voltage to less than 10V.

WARNING!

INPUT SIGNALS IN EXCESS OF 10V PEAK CAN DAMAGE THE INPUT CIRCUITS WHEN THE RANGE IS LOCKED!

3. Place an I.C. test clip on U112.
4. Connect pins 15, 1, 10 and 9 to pin 16(+5V) or pin 8(gnd) as indicated in Figure 7.1.
5. Connect Pin 11(load) to Pin 8(gnd), momentarily.
6. Set the input voltage to an amplitude that is appropriate for the selected range. The higher ranges can be checked with a 10V input signal, by making measurements and calculating the gain of the attenuator and INPUT BUFFER.

				Pin			
Range	Input Volts	Atten.	Gain	15	1	10	9
0	0.010 - 0.032	1	64.0	open	open	open	pin 8
1	0.032 - 0.100	1	19.9	pin 16	open	open	pin 8
2	0.100 - 0.320	1	6.5	open	pin 16	open	pin 8
3	0.320 - 1.000	1	2.0	pin 16	pin 16	open	pin 8
4	1.0 - 3.2	10	6.5	open	open	pin 16	pin 8
5	3.2 - 10.0	10	2.0	pin 16	open	pin 16	pin 8
6	10 - 32	100	6.5	open	pin 16	pin 16	pin 8
7	32 - 100	100	2.0	pin 16	pin 16	pin 16	pin 8
8	100 - 300	1000	6.5	open	open	open	open

Figure 7.2 Model 6620 Attenuator/Gain Range Settings

Input RANGE 3 should be checked first because it is the simplest. The attenuator is checked by measuring the ac voltage across R10. For this range the voltage should be the same as the input signal and the voltage on TP 50 should be twice the input signal's. Repeat this proceedure for the remaining ranges using the information in the preceeding figures.

If the above procedure does not localize the error, the AUTO-RANGE control circuit should be checked. This is done by, first locking the input range to range 3 and setting the input signal amplitude to 1.2V. Check the dc voltage on TP 64, it should be greater than 10V dc Now set the input Voltage to .25V ac and check TP 64, it should be more negative than -10V.

If the malfunction is still not found, it is most likely in the control logic, Q102, Q105, and U104; or in the timer circuit, U108.

7.6.2 Input Buffer

To check the INPUT BUFFER for properr operation lock the Input Range to range 3. With a 0.5V ac signal on the input, the signal on TP50 should be 1.0V ac with no dc offset. If this is incorrect check the signal on the gate of Q30, it should be 0.5V ac with no dc offset. If the ac signal is incorrect the most likely cause is in the auto-range or attenuator circuits. If the dc is not near zero, check Q30, CR21 and CR26.

If the signal on Q30's gate is correct but there is a large dc level on TP50, check the internal bias level to find the source of the malfunction. If, however, the dc is zero but the ac is incorrect, check the gain setting resistors and relays. Next, check the auto-range circuit.

7.6.3 Gain Stage

If the signal amplitude on TP 50 is between 0.6V and 2.0V check the signal on TP 169. It should be a clipped sinewave,centered on zero volts dc, and with an amplitude of approximately 7.0V peak-to-peak. If this signal is present then this circuit is most likely functioning properly.

When a signal is present but at a lower amplitude and with a dc offset, select squarewave mode for that channel and recheck the signal on TP169. If the signal is now correct this circuit is most likely functioning properly, check the sinewave to squarewave convertor and the symmetry control loop.

If still not working check the signal on the junction of R146 and R147, it should be a sinewave with a small flat segment at each zero crossing with no dc offset. When the malfunction is still not found, check the internal bias levels of this amplifier.

7.6.4 Sinewave-to-Squarewave Converter

The four outputs of the two comparators should be square waves with a lower value of approximately +0.4V and an upper value of approximately +3.0V. If these signals are not present, check the supply voltages on pin 4 (-5.6V) and pin 8 (+5.0V). When no error is found, the input signals at pin 2 of IC's, U181 and 187, should be checked. The signals at these pins should be a very clipped sine wave, almost a square wave, with an amplitude of approximately 1.3Vp-p and crossing zero volts. If these signals exists, the comparator is most likely defective and therefore should be replaced. If these signals are not correct, double check the gain stage's output signal (TP169). If they are correct, and the components connected to pin 2 are OK, then the comparator should be replaced.

7.6.5 Symmetry Correction Loop

When the gain stage's output signal is incorrect in sinewave mode but correct in squarewave mode, this circuit is probably malfunctioning. First, in Squarewave Mode, check for a 0.6V peak to peak squarewave on pin 6 of U224, if this signal is either missing or incorrect the problem is in the symmetry detector, otherwise the control loop is malfunctioning.

In the symmetry detector, check the reference voltages on VR207 and VR221, they should be 6.4V ±5%. Next check for a Squarewave on pin 2 of U224, if present U224 is probable defective.

The voltage on TP196 should equal the emitter of Q201, if not check the operation of U196, Q199 and Q202.

7.6.6 Main Flip-Flop

First check for squarewave signals on pins 1, 2, 14 and 15 of U632. If one or more of these signals are missing check for signals on the input of U632 pins 3, 4, 5, 6, 10, 11, 12 and 13. If the output signals are present check for a pulse on pin 3 and 14 of U656. This circuit is working properly when these pulses are present.

7.6.7 Current Source and Switch

The current source can be checked by first measuring the voltage between pin 1 and pin 2 of U683. If this is as shown on the schematic and the voltage between pin 1 of U683 and pin 2 of U682 is less than 10 mV than the current source is working correctly. Next, check R690 for a pulse of 0.7V peak to peak, if not present check the operation of Q665 and Q667.

7.6.8 Pulse Filter Circuit

The voltage on the emitter of Q734 should be approximatly 1V more positive than on the emitter of Q720, if not, check Q731, Q732, U734 and Q734. The DC voltage on R690 should be zero, if not, check the operation of U720 and Q720.

SECTION 8

SCHEMATIC DIAGRAMS AND PC BOARD LAYOUTS

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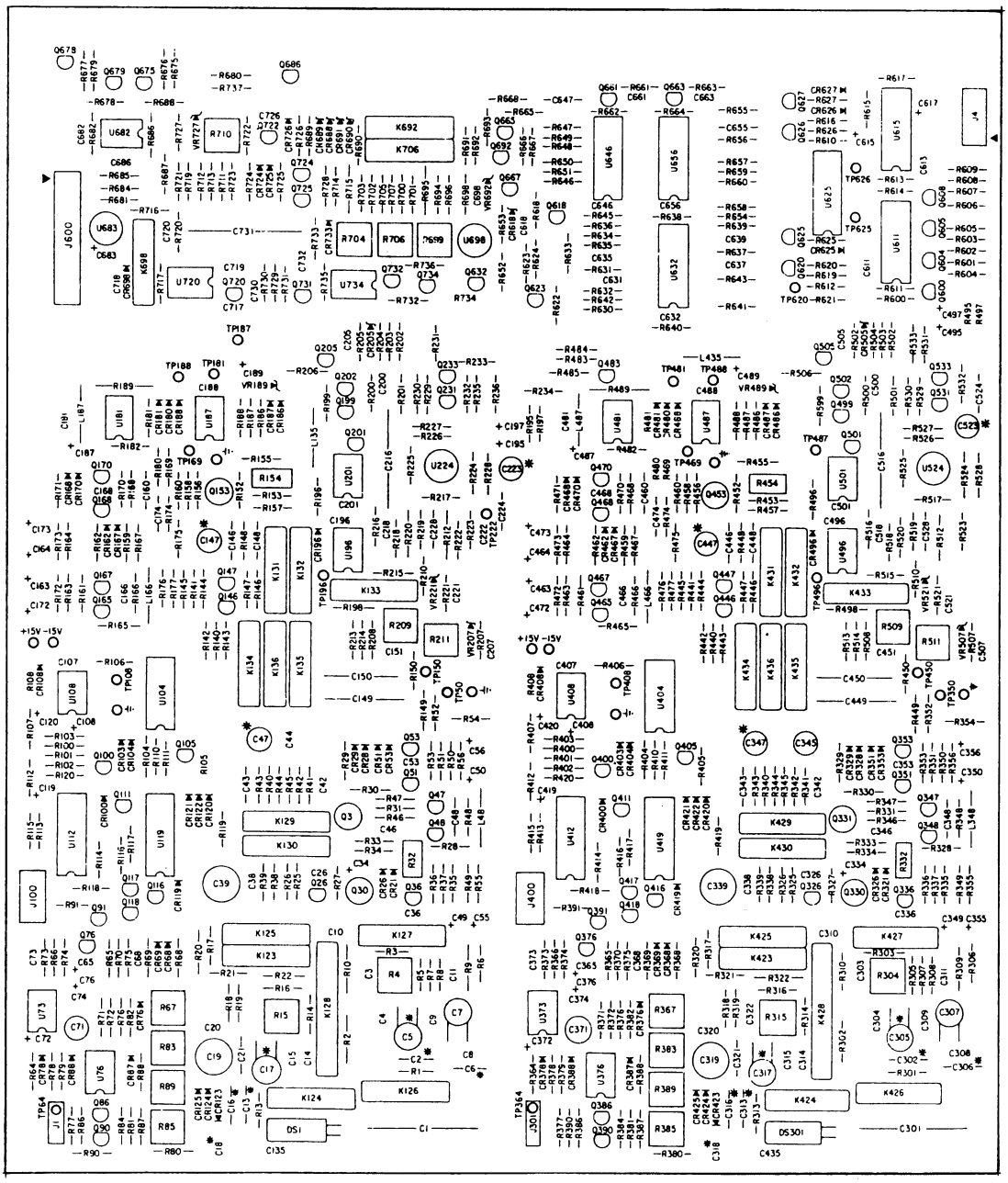
8.7	IEEE-488 Interface	8-11
8.8	Serial Interface (Optional RS-232C)	8-12

Figure 8.1, 8.2, 8.3
PC Board Layout



* DELETED IN MODEL 6600

COMPONENT PCB LAYOUT OF
REFERENCE CHANNEL, SIGNAL CHANNEL
AND PHASE TO VOLTAGE CONVERTER
FIGURES 8.1, 8.2 AND 8.3

TO J1010 FIGURE 8.5

J100

AUTO RANGE

ATTENUATORS

INPUT LEVEL DETECTORS

INPUT BUFFER

SAIN STAGE

SINE/SQUARE CONVERTOR

SYMMETRY CORRECTION CIRCUIT

NOTES:

ALL RESISTORS IN OHMS, 1/4W 1% UNLESS OTHERWISE SPECIFIED.

CIRCUIT GROUND

CHASSIS GROUND

PCB GROUND

CAPACITOR IN pF/V

CIRCUIT BOARD CONTROLLED

REAR PANEL CONTROLLED

FRONT PANEL CONTROLLED

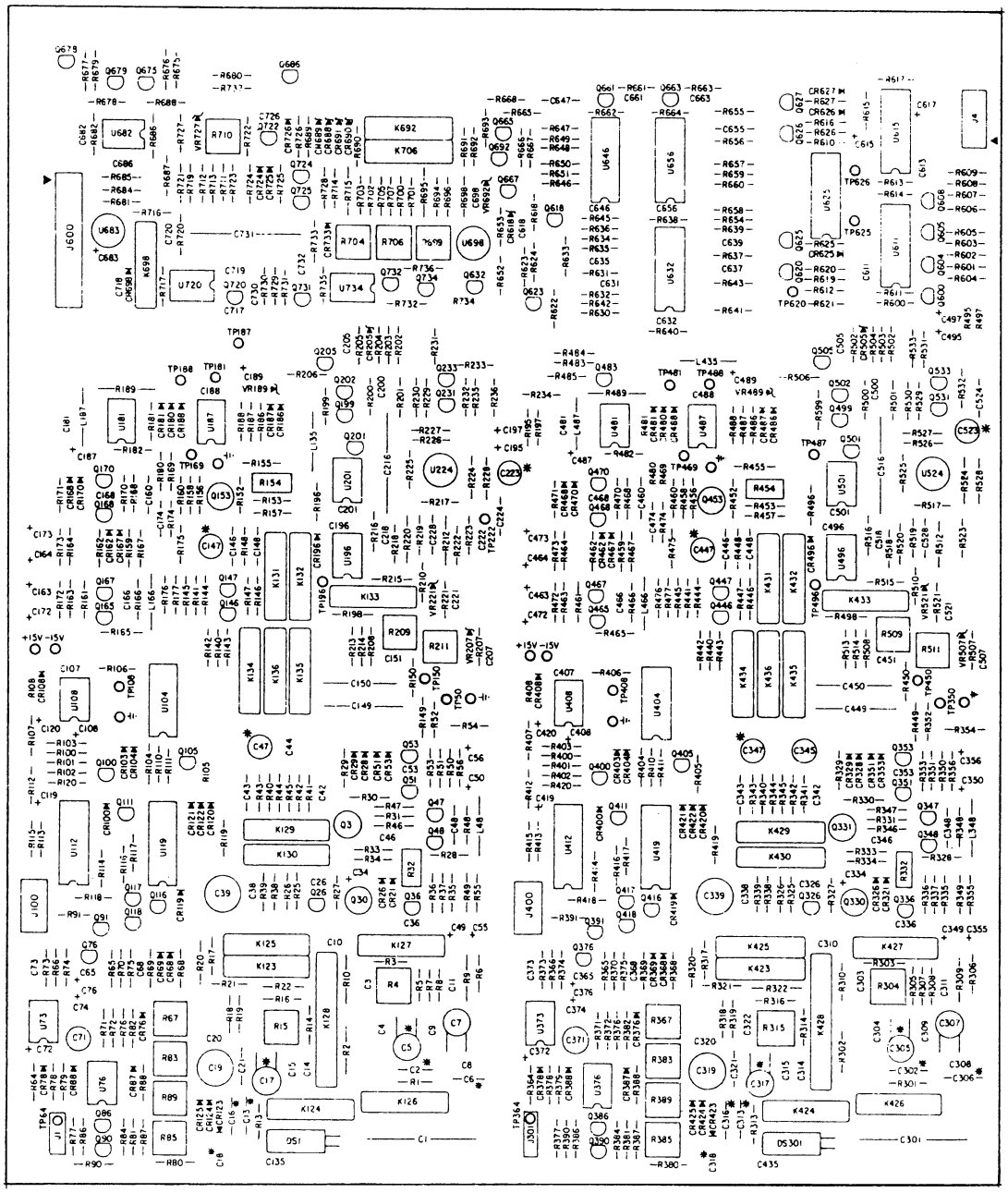
* FOR TRIM OPTION

** 4-5% DEPOLARIZED

5610 5620	REFERENCE CHANNEL			
8.1	9-24-92	5519	2 of 3	

KH KROHN-HITE CORPORATION

Figure 8.1, 8.2, 8.3
PC Board Layout



* DELETED IN MODEL 6600

COMPONENT PCB LAYOUT OF
REFERENCE CHANNEL, SIGNAL CHANNEL
AND PHASE TO VOLTAGE CONVERTER
FIGURES 8.1, 8.2 AND 8.3

AUTO RANGE

INPUT LEVEL DETECTORS

GAIN STAGE

SINE/SQUARE CONVERTER

SYMMETRY CORRECTION CIRCUIT

ATTENUATORS

INPUT BUFFER

NOTES:

ALL RESISTORS IN OHMS, 1/4W 1% UNLESS OTHERWISE SPECIFIED.

⏚ CIRCUIT GROUND

▽ PROGRAM GROUND

○ TEST POINT

⏚ CHASSIS GROUND

Ø CIRCUIT BOARD CONTROLLED

Ø REAR PANEL CONTROLLED

Ø FRONT PANEL CONTROLLED

‡ LOW BAND OPTION

* +5V DECOUPLED

MODEL 6610 6620	TITLE SIGNAL CHANNEL		REV A
FIG. NO. 8.2	DATE 9-24-92	DRAFT NO. 4959	SHEET 1 OF 3
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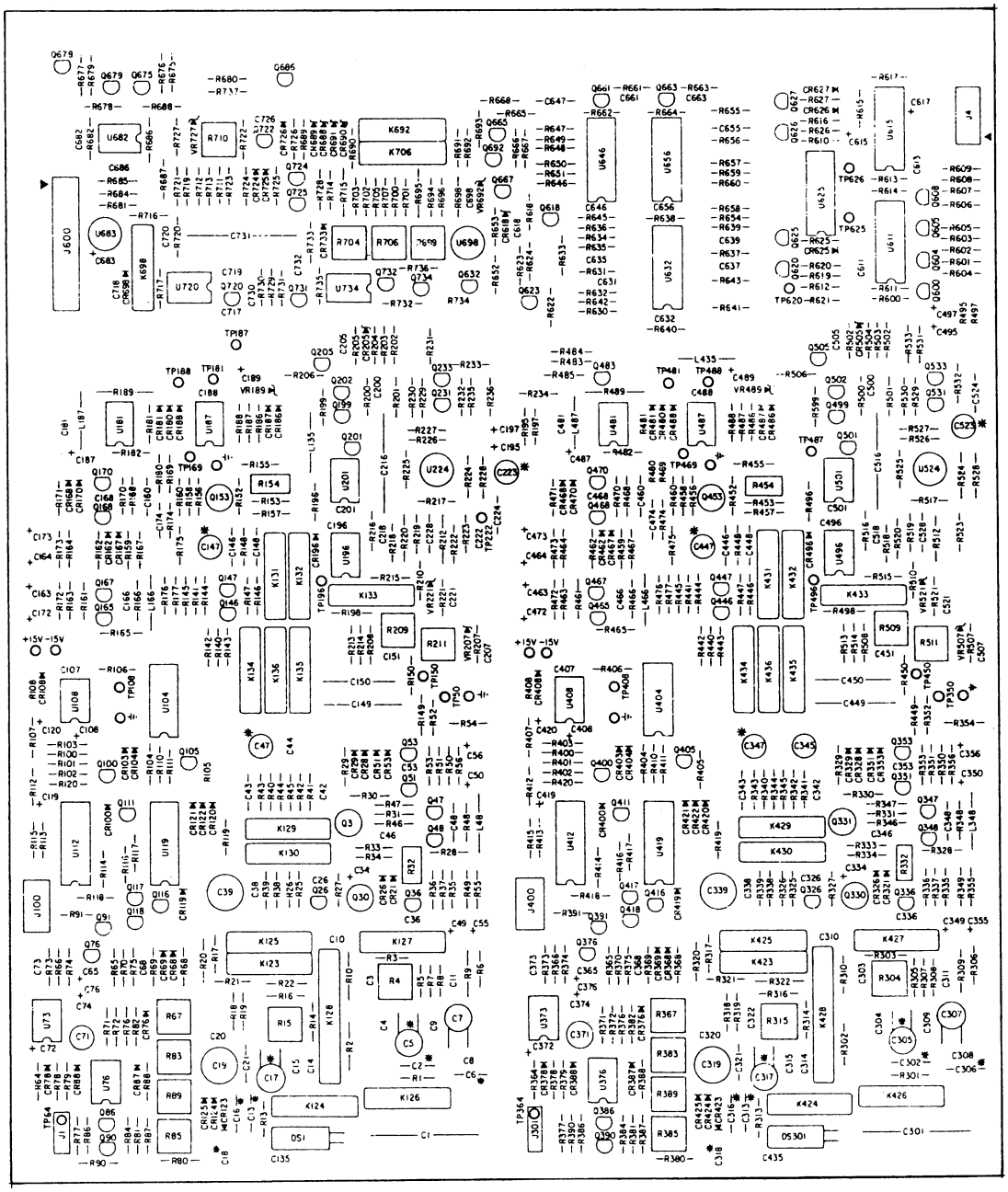
Figure 8.1, 8.2, 8.3
PC Board Layout



* DELETED IN MODEL 6600

COMPONENT PCB LAYOUT OF
REFERENCE CHANNEL, SIGNAL CHANNEL
AND PHASE TO VOLTAGE CONVERTER
FIGURES 8.1, 8.2 AND 8.3

TO J1020 FIGURE 8.5

PULSE GENERATOR

REFERENCE CHANNEL

SIGNAL CHANNEL

MAIN FLIP-FLOP

J600

SQUARE/SINE

360° CAL

0° CAL

0-360°±180

DELETE FOR 6600

2.00K FOR 6600 ONLY

ADD FOR 6600

SYMMETRY PULLING JUNCTION R222, C222

FREQUENCY DETECTORS

FROM REF CHANNEL 1ST STAGE OUTPUT AFTER R52

J680

TO J1101 FIGURE 8.6

Ø360°CAL

Ø180° CAL

Ø0°CAL

DELETE FOR MODEL 6600

NOTES:

ALL RESISTOR IN OHMS, 1/4W 1% UNLESS OTHERWISE SPECIFIED

- CIRCUIT GROUND
- PROGRAM GROUND
- TEST POINT
- CHASSIS GROUND
- CIRCUIT BOARD CONTROLLED
- REAR PANEL CONTROLLED
- FRONT PANEL CONTROLLED

* LOW BAND OPTION

MODEL 6600 SERIES	TITLE PHASE TO VOLTAGE CONVERTER	REV A
FIG. No. 8.3	DATE 9-24-92	LAST ECN No. 4959	SHEET 3 OF 3

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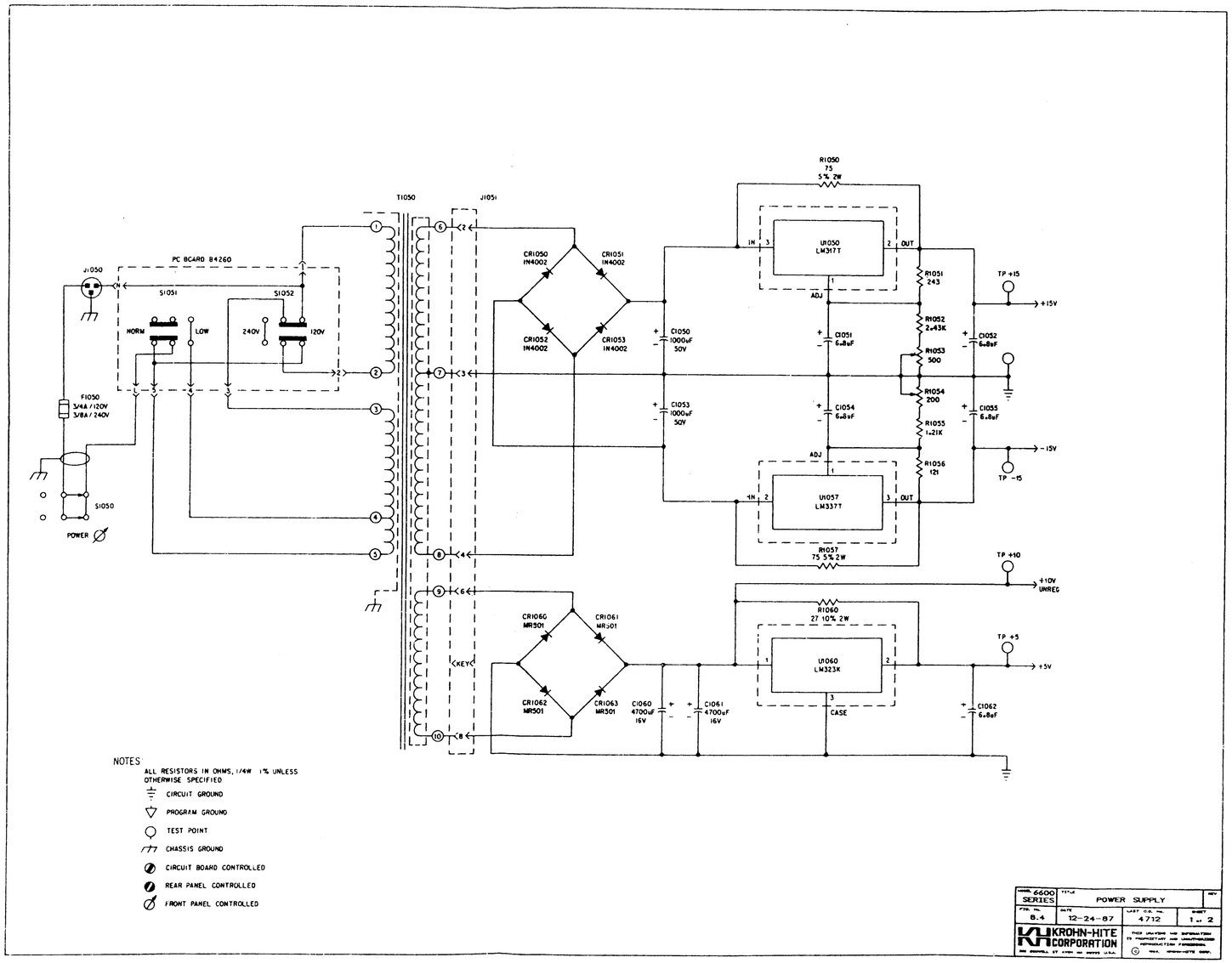
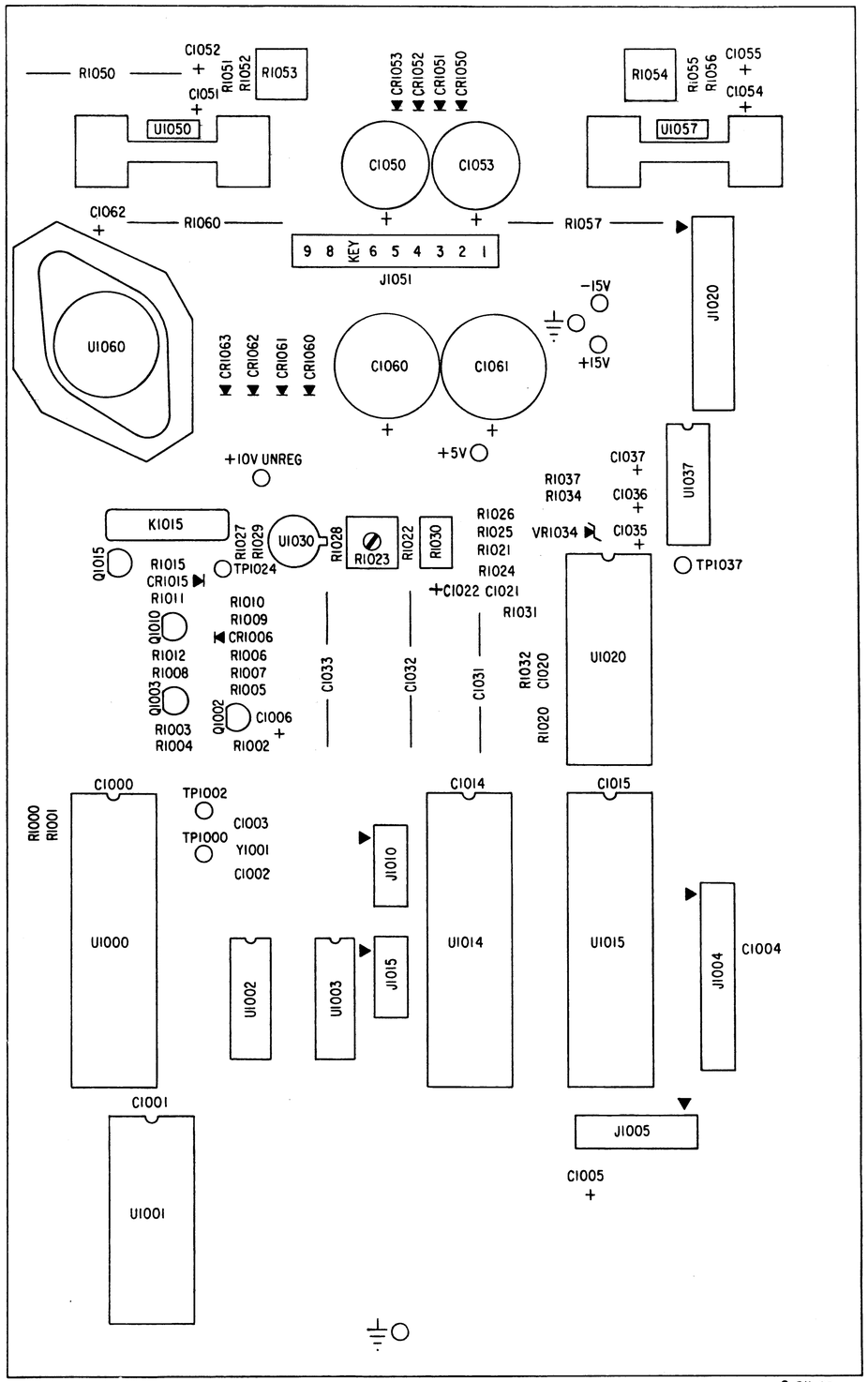
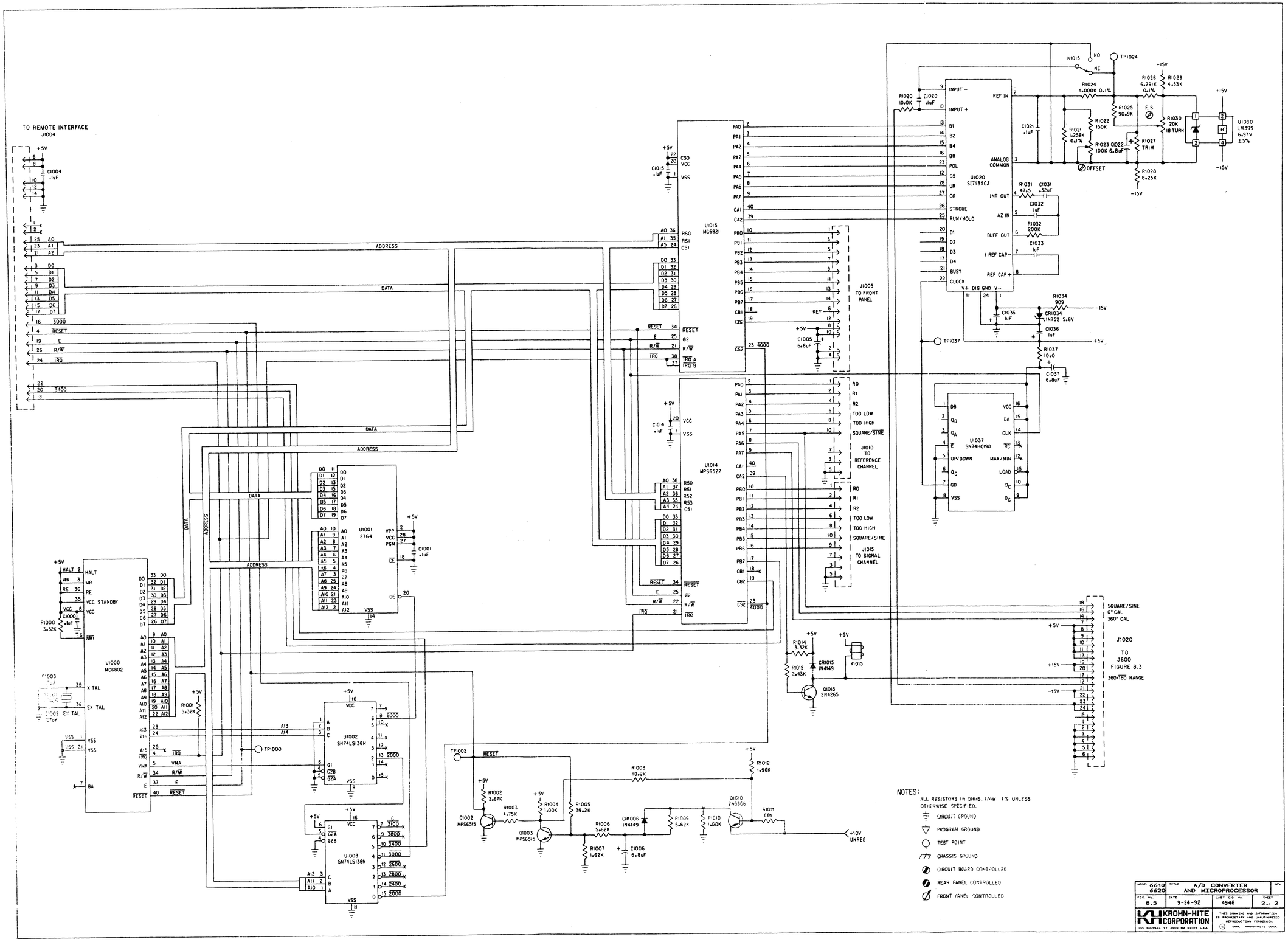




9-24-92

COMPONENT PCB LAYOUT OF
POWER SUPPLY, A/D CONVERTER
AND MICROPROCESSOR
FIGURE 8.4 AND 8.5


TO REMOTE INTERFACE J1004
U1000 MC6802
U1001 2764
U1002 SN74LS138N
U1003 SN74LS138N
U1014 MPS6522
U1015 MC6821
U1020 SI7135CJ
U1037 SN74HC190
J1005 TO FRONT PANEL
J1010 TO REFERENCE CHANNEL
J1015 TO SIGNAL CHANNEL
J1020 TO J600 FIGURE 8.3
ADDRESS
DATA
RESET
+5V
-15V
+10V UNREG
TP1000
TP1002
TP1024
TP1037
K1015
K1013
Q1002 MPS6515
Q1003 MPS6515
Q1010 2N3906
Q1015 2N4265
CR1006 IN4149
CR1015 IN4149
CR1034 IN752 5.6V
NOTES:
ALL RESISTORS IN OHMS, 1/4W 1% UNLESS OTHERWISE SPECIFIED.
CIRCUIT GROUND
PROGRAM GROUND
TEST POINT
CHASSIS GROUND
CIRCUIT BOARD CONTROLLED
REAR PANEL CONTROLLED
FRONT PANEL CONTROLLED
MODEL 6610 6620
TITLE A/D CONVERTER AND MICROPROCESSOR
REV
FIG. No. 8.5
DATE 9-24-92
LAST C.O. No. 4948
SHEET 2, 2
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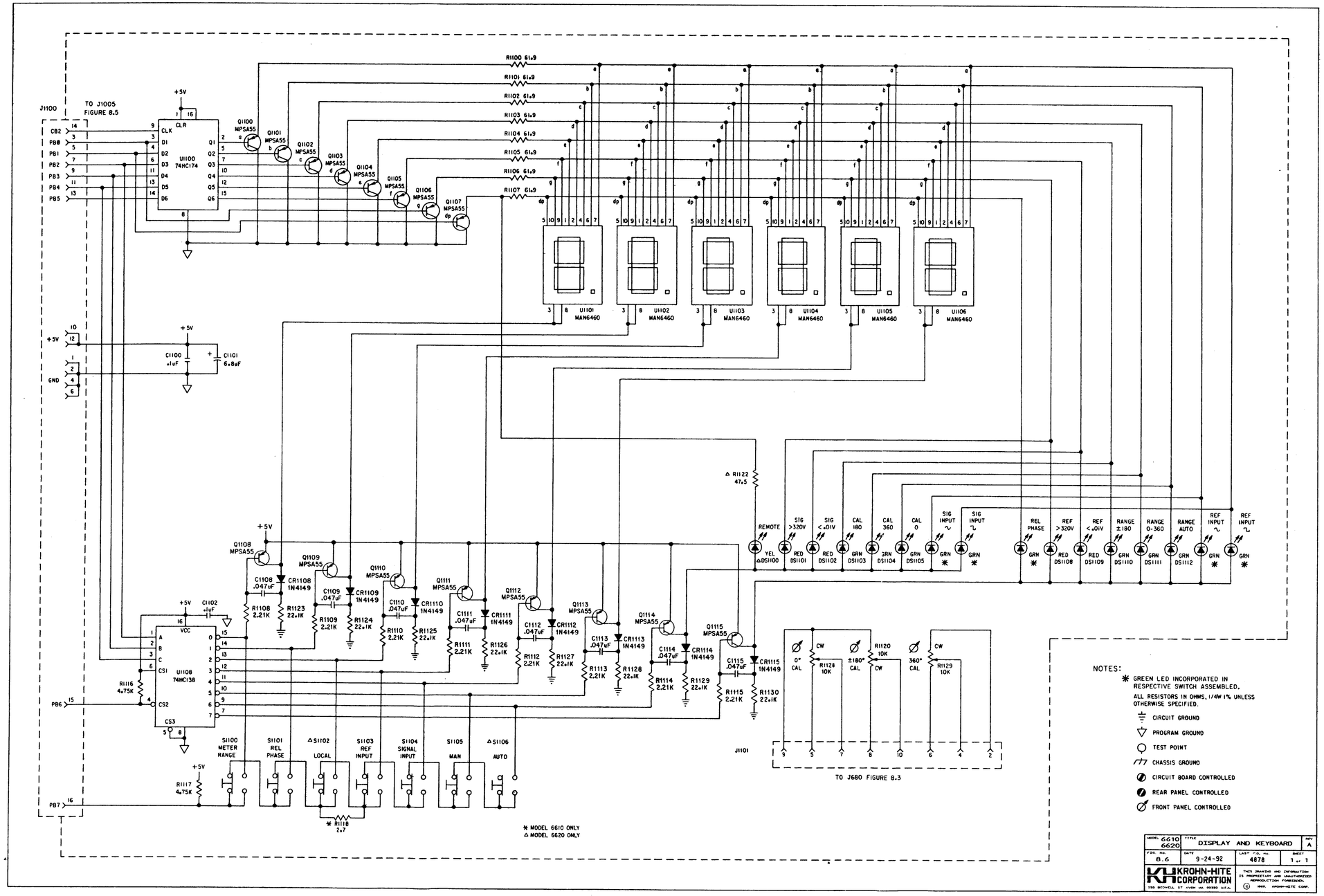

NOTES:

* GREEN LED INCORPORATED IN RESPECTIVE SWITCH ASSEMBLED. ALL RESISTORS IN OHMS, 1/4W 1% UNLESS OTHERWISE SPECIFIED.

⏚ CIRCUIT GROUND

▽ PROGRAM GROUND

○ TEST POINT

CHASSIS GROUND

◪ CIRCUIT BOARD CONTROLLED

◧ REAR PANEL CONTROLLED

⌀ FRONT PANEL CONTROLLED

MODEL 6610 6620	TITLE: DISPLAY AND KEYBOARD		REV A
ECO No. 8.6	DATE 9-24-92	LAST ECO No. 4878	SHEET 1 of 1

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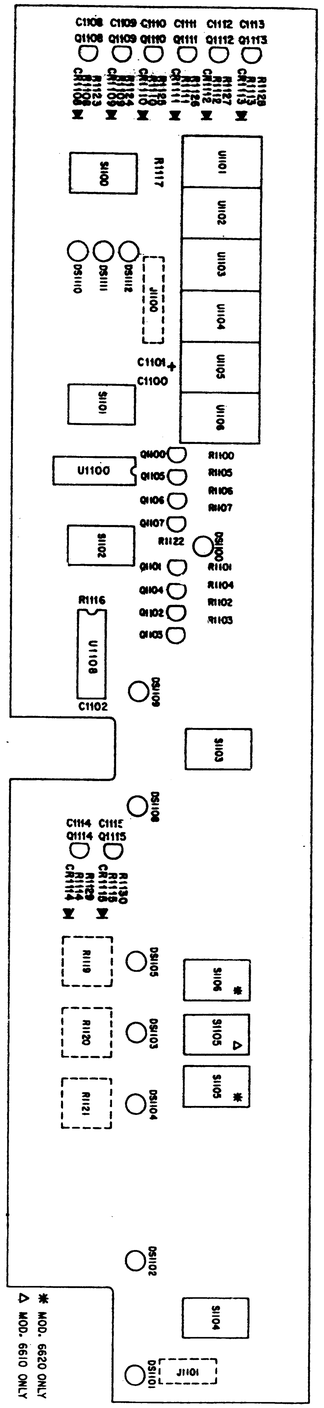
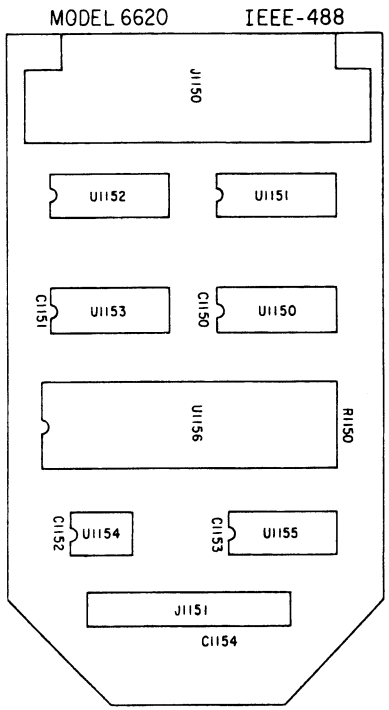


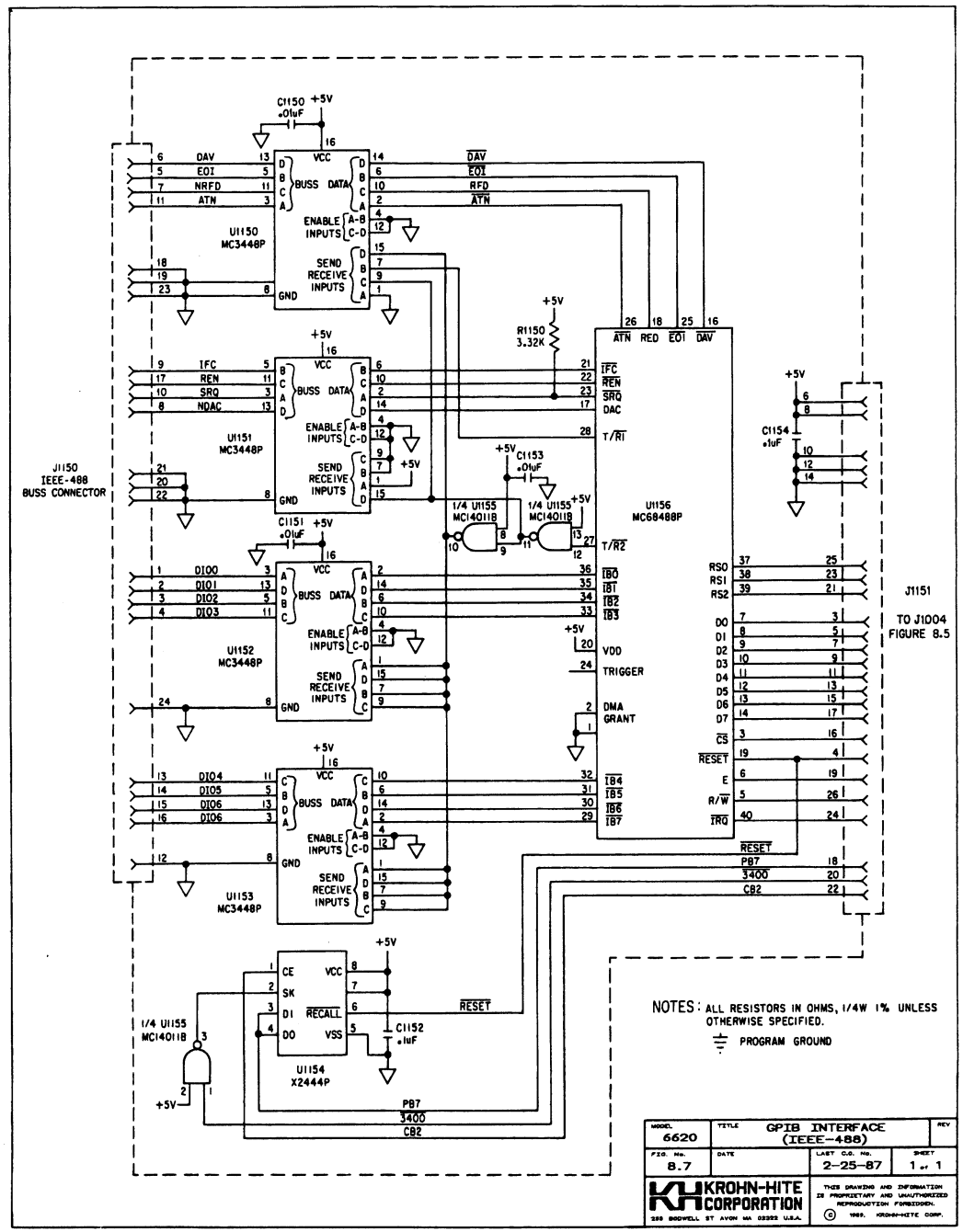
COMPONENT PCB LAYOUT OF FRONT PANEL DISPLAY AND KEYBOARD
FIGURE 8.6

* MODEL 6620 ONLY
Δ MODEL 6610 ONLY

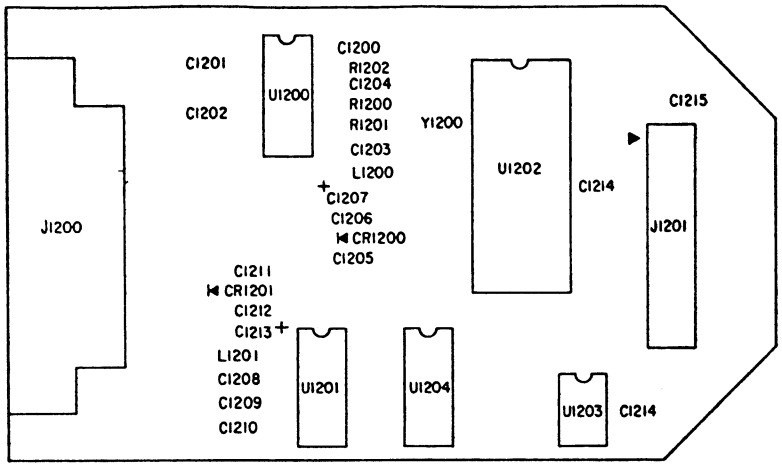


IEEE-488 PARTS LIST

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART#
C1150	0.01uF 20% 500V	SP	5GAS-S10	412310
C1151	0.01uF 20% 500V	SP	5GAS-S10	412310
C1152	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1153	0.01uF 20% 500V	SP	5GAS-S10	412310
C1154	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
J1150	Connector IEEE-488	AMP	552633-4	015006
J1151	Connector 26 Pin Male	MLX	39-26-7265	015039
R1150	3.32K 1% 1/4W	PRP	GP1/4W-T100	927233
U1150	IC GPIB Buffer	MOT	MC3448AP	203448
U1151	IC GPIB Buffer	MOT	MC3448AP	203448
U1152	IC GPIB Buffer	MOT	MC3448AP	203448
U1153	IC GPIB Buffer	MOT	MC3448AP	203448
U1154	IC Eaprom 16 X 16	XI	X2444P	202444
U1155	IC Quad 2 Input Nand Gate	MOT	MC14011B	201401
U1156	IC GPIB Interface	MOT	MC68488P	208488

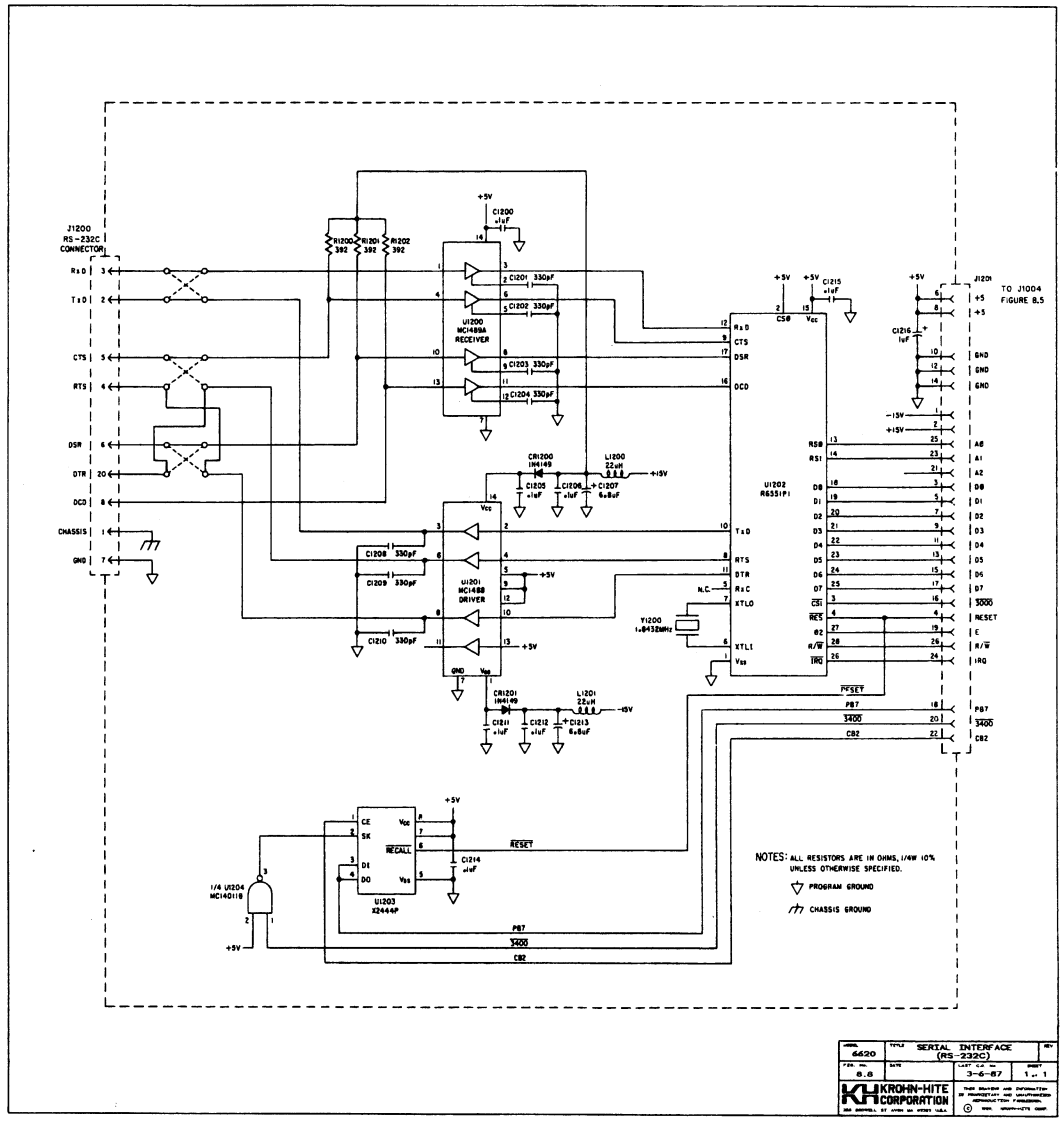


COMPONENT PCB LAYOUT OF RS-232C



RS232C OPTION PARTS LIST

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART#
C1200	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1201	330pF 5% 500V	KGN	DM15C331J	423133
C1202	330pF 5% 500V	KGN	DM15C331J	423133
C1203	330pF 5% 500V	KGN	DM15C331J	423133
C1204	330pF 5% 500V	KGN	DM15C331J	423133
C1205	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1206	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1207	6.8uF 20% 35V	KEM	T350F685M035AS	471568
C1208	330pF 5% 500V	KGN	DM15C331J	423133
C1209	330pF 5% 500V	KGN	DM15C331J	423133
C1210	330pF 5% 500V	KGN	DM15C331J	423133
C1211	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1212	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1213	6.8uF 20% 35V	KEM	T350F685M035AS	471568
C1214	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1215	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1216	1uF 20% 50V	MAL	TE1300	471511
CR1200	Diode Switching	NS	1N4149	234149
CR1201	Diode Switching	NS	1N4149	234149
J1200	Connector RS-232C	AMP	206604-1	015008
J1201	Connector 26 Pin Male	MLX	39-26-7265	015039
L1200	Choke 22uH 10% 1/4W	DLV	1537-44	001009
L1201	Choke 22uH 10% 1/4W	DLV	1537-44	001009
R1200	392 1% 1/4W	PRP	GP1/4W-T100	928139
R1201	392 1% 1/4W	PRP	GP1/4W-T100	928139
R1202	392 1% 1/4W	PRP	GP1/4W-T100	928139
U1200	IC Receiver	MOT	MC1489AP	201489
U1201	IC Driver	MOT	MC1488P	201488
U1202	IC VART	MLX	R6551P1	286551
U1203	IC Eaprom 16 X 16	XI	X2444P	202444
U1204	IC Quad 2 Input Nand Gate	MOT	MC14011B	201401
Y1200	Crystal 1.8432MHz	MTR	VR-184	290184



SECTION 9

PARTS LIST

9.1 ORDERING INFORMATION

When ordering parts from Krohn-Hite, specify the instrument model number, serial number, schematic reference designation (ie; R, C, CR, etc.) and the manufacturer's part number (see the list below for the Manufacturer's abbreviation and FSCM number).

Address all inquiries to your local Krohn-Hite Sales Representative or directly to Krohn-Hite.

Any engineering modifications will be found on a Modifications Sheet inside the rear cover of this manual.

The part numbers listed are either the actual parts used or direct replacements.

9.2 ORDERING UNLISTED PARTS

When ordering parts from Krohn-Hite that are not listed, include the instrument model number, serial number, a description and location of the part.

MFR	NAME	FSCM
AB	Allen Bradley Milwaukee, WI 53204	01121
AMP	Amp Inc. Harrisburg, PA 17105	-----
ASZ	American Shizuki Ogallalla, NE 69513	84411
APH	Amphenol Lisle, IL 60532	29587
BKM	Beckman Fullerton, CA 92635	73138
BOU	Bourns Riverside, CA 92507	-----
BUS	Bussman St. Louis, MO 63178	71400
CD	Compensated Devices Melrose, MA 02167	-----
CST	Clarostat Dover, NH 03820	-----
DGT	ITT Shadow Edin Prairie, MN 55344	-----
DI	Diodes Inc Chatsworth, CA 91311	-----
DLV	American Precision (Delevon) East Aurora, NY 14052	99800
KEM	Kemet Greenville, NC 29606	-----
KH	Krohn-Hite Avon, MA 02322	88865
ME	Murata Erie Smyrna, GA 30080	-----

MFR	NAME	FSCM
MOT	Motorola Pheonix, AZ 85072	04713
MLX	Molex Lisle, IL 60532	-----
MTR	M Tron Yankton, SD 57078	-----
NS	National Semiconductor Santa Clara, CA 95052	27014
PRP	Precision Resistive Products Mediapolis, IA 52637	-----
QC	Quality Components St. Mary, PA 15857	-----
MEP	Mepco Electra Mineral Wells, TX 76067	-----
ROM	Rohm Corp. Irvine, CA 92718	-----
SP	Sprague Electric Co. Lexington, MA 02173	56289
SLX	Siliconix Inc. Santa Clara, CA 95054	-----
STT	Stetco Inc. Franklin Park, IN 60131	52763
SYL	Sylvania Hillsboro, NH 03244	-----
TI	Texas Instrument Dallas, TX 75265	01295
TOM	Thompson Corp. Woodlawn, CA 91367	-----
VOL	Voltronics Corp. East Hanover, NJ 07936	-----

Table 1. Manufacturer's Abbreviation and FSCM Number.

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
C1	1uF +0.5%-3.5% 200V	ASZ	X363UW	452510
C2	1pF 10% 500V	QC	9206-01910	411001
C3	36pF 10% 500V	KGN	DM15C360K	422036
C4	18pF 5% 500V	KGN	DM15C180J	422018
C5	0.6 - 9pF Trimmer	VOL	EF9	483002
C6	4.7pF 10% 500V	QC	9210-47910	411947
C7	0.6 - 9pF Trimmer	VOL	EF9	483002
C8	Trim		———	
C9	120pF 5% 500V	KGN	DM15C121J	422112
C10	8pF .5pF 500V	KGN	DM15602112-5	422008
C11	Trim		———	
C13	1pF 10% 500V	QC	9206-01910	411001
C15	18pF 5% 500V	KGN	DM15C180J	422018
C16	1pF 10% 500V	QC	9206-01910	411001
C17	0.6 - 9pF Trimmer	VOL	EF9	483002
C18	24pF 10% 500V	KGN	DM15C240K	423024
C19	10-60pF Trimmer	STT	10S-TRIKO-06N1500	482010
C20	Trim		———	
C21	1500pF 5% 100V	KGN	DM19C152J	422215
C22	975pF 1% 500V	KGN	DM15C975OF	421197
C23	150pF 5% 500V	KGN	DM15C151K	422115
C26	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C34	1uF 20% 35V	KEM	T350A105M035AF	471510
C36	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C38	270pF 1% 500V	KGN	DM15C271F	421127
C39	10-60pF Trimmer	STT	10S-TRIKO-06N1500	482010
C42	89pF 1% 500V	KGN	DM15C890F	421089
C43	2pF 10% 500V	QC	9208-20910	411002
C44	22pF 10% 500V	KGN	DM15C220K	423022
C46	56pF 10% 500V	KGN	DM15C560K	422056
C47	2.5-6pF Trimmer	STT	7S-TRIKO-02N033	482002
C48	6.2pF 10% 500V	QC	9212-62910	411962
C49	6.8uF 20% 35V	SP	T350F685M035AS	471568
C50	6.8uF 20% 35V	SP	T350F685M035AS	471568
C53	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C55	6.8uF 20% 35V	SP	T350F685M035AS	471568
C56	6.8uF 20% 35V	SP	T350F685M035AS	471568
C65	1uF 20% 35V	KEM	T350A105M035AF	471510
C68	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C71	7-35pF Trimmer	STT	7S-TRIKO-02-N1500	482009
C72	1uF 20% 35V	KEM	T350A105M035AF	471510
C73	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C74	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C76	6.8uF 20% 35V	SP	T350F685M035AS	471568
C107	4700pF 20% 1000V	SP	5GA-D47	412247
C108	1uF 20% 35V	KEM	T350A105M035AF	471510
C119	1uF 20% 35V	KEM	T350A105M035AF	471510
C120	6.8uF 20% 35V	SP	T350F685M035AS	471568
C135	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C146	5.6pF 10% 500V	QC	9210-56910	411956
C147	3-9pF Trimmer	STT	7S-TRIKO-02-NO75	482003
C148	10pF 10% 500V	QC	9213-10110	411010
C149	0.1uF +1%-3% 200V	ASZ	X363UW	452410
C150	0.032uF +1%-3% 200V	ASZ	X363UW	452332
C160	3.9pF 10% 500V	QC	9210-39910	411939

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
C163	6.8uF 20% 35V	SP	T350F685M035AS	471568
C164	6.8uF 20% 35V	SP	T350F685M035AS	471568
C166	18pF 5% 500V	KGN	DM15C180J	422018
C168	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C172	6.8uF 20% 35V	SP	T350F685M035AS	471568
C173	6.8uF 20% 35V	SP	T350F685M035AS	471568
C174	1.5pF 10% 500V	QC	9207-15910	411915
C181	27pF 5% 500V	KGN	DM15C270J	422027
C187	6.8uF 20% 35V	SP	T350F685M035AS	471568
C188	150pF 10% 500V	KGN	DM15C151K	422115
C189	6.8uF 20% 35V	SP	T350F685M035AS	471568
C195	6.8uF 20% 35V	SP	T350F685M035AS	471568
C196	0.047uF 20% 50V	ME	RPE110Z5U473M50V	413347
C197	6.8uF 20% 35V	SP	T350F685M035AS	471568
C200	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C201	100pF 10% 500V	KGN	DM15C101K	422110
C205	4700pF 20% 1000V	SP	5GA-D47	412247
C207	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C216	0.32uF +1%-3% 200V	ASZ	X363UW	452432
C218	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C221	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C222	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C223	3-9pF Trimmer	STT	7S-TRIKO-02-NO75	482003
C224	3.9pF 10% 500V	QC	9210-39910	411939
C228	3.9pF 10% 500V	QC	9210-39910	411939
C230	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C301	1uF +0.5%-3.5% 200V	ASZ	X363UW	452510
C302	1pF 10% 500V	QC	9206-01910	411001
C303	36pF 10% 500V	KGN	DM15C360K	422036
C304	18pF 5% 500V	KGN	DM15C180J	422018
C305	0.6 - 9pF Trimmer	VOL	EF9	483002
C306	4.7pF 10% 500V	QC	9210-47910	411947
C307	0.6 - 9pF Trimmer	VOL	EF9	483002
C308	Trim		———	
C309	120pF 5% 500V	KGN	DM15C121J	422112
C310	8pF .5pF 500V	KGN	DM15602112-5	422008
C311	Trim		———	
C313	1pF 10% 500V	QC	9206-01910	411001
C315	18pF 5% 500V	KGN	DM15C180J	422018
C316	1pF 10% 500V	QC	9206-01910	411001
C317	0.6 - 9pF Trimmer	VOL	EF9	483002
C318	24pF 10% 500V	KGN	DM15C240K	423024
C319	10-60pF Trimmer	STT	10S-TRIKO-06N1500	482010
C320	Trim		———	
C321	1500pF 5% 100V	KGN	DM19C152J	422215
C322	975pF 1% 500V	KGN	DM15C975OF	421197
C323	150pF 5% 500V	KGN	DM15C151K	422115
C326	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C334	1uF 20% 35V	KEM	T350A105M035AF	471510
C336	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C338	270pF 1% 500V	KGN	DM15C271F	421127
C339	10-60pF Trimmer	STT	10S-TRIKO-06N1500	482010
C342	89pF 1% 500V	KGN	DM15C890F	421089
C343	2pF 10% 500V	QC	9208-20910	411002
C345	7-35pF Trimmer	STT	7S-TRIKO-02-N1500	482009

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
C346	56pF 10% 500V	KGN	DM15C560K	422056
C347	2.5-6pF Trimmer	STT	7S-TRIKO-02N033	482002
C348	6.2pF 10% 500V	QC	9212-62910	411962
C349	6.8uF 20% 35V	SP	T350F685M035AS	471568
C350	6.8uF 20% 35V	SP	T350F685M035AS	471568
C353	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C355	6.8uF 20% 35V	SP	T350F685M035AS	471568
C356	6.8uF 20% 35V	SP	T350F685M035AS	471568
C365	1uF 20% 35V	KEM	T350A105M035AF	471510
C368	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C371	7-35pF Trimmer	STT	7S-TRIKO-02-N1500	482009
C372	1uF 20% 35V	KEM	T350A105M035AF	471510
C373	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C374	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C376	6.8uF 20% 35V	SP	T350F685M035AS	471568
C407	4700pF 20% 1000V	SP	5GA-D47	412247
C408	1uF 20% 35V	KEM	T350A105M035AF	471510
C419	1uF 20% 35V	KEM	T350A105M035AF	471510
C420	6.8uF 20% 35V	SP	T350F685M035AS	471568
C435	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C436	6.8uF 20% 35V	SP	T350F685M035AS	471568
C446	5.6pF 10% 500V	QC	9210-56910	411956
C447	3-9pF Trimmer	STT	7S-TRIKO-O2-NO75	482003
C448	10pF 10% 500V	QC	9213-10110	411010
C449	0.1uF +1%-3% 200V	ASZ	X363UW	452410
C450	0.032uF +1%-3% 200V	ASZ	X363UW	452332
C460	3.9pF 10% 500V	QC	9210-39910	411939
C463	6.8uF 20% 35V	SP	T350F685M035AS	471568
C464	6.8uF 20% 35V	SP	T350F685M035AS	471568
C466	18pF 5% 500V	KGN	DM15C180J	422018
C468	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C472	6.8uF 20% 35V	SP	T350F685M035AS	471568
C473	6.8uF 20% 35V	SP	T350F685M035AS	471568
C474	1.5pF 10% 500V	QC	9207-15910	411915
C476	Trim			———
C481	27pF 5% 500V	KGN	DM15C270J	422027
C487	6.8uF 20% 35V	SP	T350F685M035AS	471568
C488	150pF 10% 500V	KGN	DM15C151K	422115
C489	6.8uF 20% 35V	SP	T350F685M035AS	471568
C495	6.8uF 20% 35V	SP	T350F685M035AS	471568
C496	0.047uF 20% 50V	ME	RPE110Z5U473M50V	413347
C497	6.8uF 20% 35V	SP	T350F685M035AS	471568
C500	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C501	100pF 10% 500V	KGN	DM15C101K	422110
C505	4700pF 20% 1000V	SP	5GA-D47	412247
C507	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C516	0.32uF +1%-3% 200V	ASZ	X363UW	452432
C518	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C521	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C523	3-9pF Trimmer	STT	7S-TRIKO-O2-NO75	482003
C524	3.9pF 10% 500V	QC	9210-39910	411939
C528	3.9pF 10% 500V	QC	9210-39910	411939
C611	0.01uF 20% 500V	SP	5GAS-S10	412310
C613	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C617	6.8uF 20% 35V	SP	T350F685M035AS	471568

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
C618	4700pF 20% 1000V	SP	5GA-D47	412247
C600	100pF 20% 100V	KGN	DM15C101K	422110
C621	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C626	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C627	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C631	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C632	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C635	15pF 5% 500V	KGN	DM15C150J	423015
C637	15pF 5% 500V	KGN	DM15C150J	423015
C639	15pF 5% 500V	KGN	DM15C150J	423015
C646	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C647	12pF 10% 500V	QC	9213-12110	411012
C655	12pF 10% 500V	QC	9213-12110	411012
C656	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C661	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C663	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C682	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C683	1uF 20% 35V	KEM	T350A105M035AF	471510
C686	100pF 10% 500V	KGN	DM15C101K	422110
C698	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C717	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C718	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C719	100pF 10% 500V	KGN	DM15C101K	422110
C720	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C726	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C730	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C731	1uF +0.5%-3.5% 200V	ASZ	X363UW	452510
C732	0.022uF 10% 250V	PLS	167022K250B	463322
C1000	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1001	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1002	27pF 5% 500V	KGN	DM15C270J	422027
C1003	27pF 5% 500V	KGN	DM15C270J	422027
C1004	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1005	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1006	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1014	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1015	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1020	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1021	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1022	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1031	0.32uF +1%-3% 200V	ASZ	X363UW	452432
C1032	1uF +0.5%-3.5% 200V	ASZ	X363UW	452510
C1033	1uF +0.5%-3.5% 200V	ASZ	X363UW	452510
C1035	1uF 20% 35V	KEM	T350A105M035AF	471510
C1036	1uF 20% 35V	KEM	T350A105M035AF	471510
C1037	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1050	1000uF 50V	SP	513D108M050EN4	471813
C1051	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1052	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1053	1000uF 50V	SP	513D108M050EN4	471813
C1054	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1055	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1060	4700uF 16V	SP	513D478M016FR4	471847
C1061	4700uF 16V	SP	513D478M016FR4	471847
C1062	6.8uF 20% 35V	SP	T350F685M035AS	471568

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
C1070	0.01uF 10% 400V	CD	WMF4S1	431311
C1100	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1101	6.8uF 20% 35V	SP	T350F685M035AS	471568
C1102	0.1uF 20% 100V	ME	RPE122Z5U104M100V	413410
C1108	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1109	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1110	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1111	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1112	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1113	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1114	0.047uF 2% 200V	ASZ	X363UW-14	451347
C1115	0.047uF 2% 200V	ASZ	X363UW-14	451347
CR21	Diode Low Leakage	NS	FD300	280300
CR26	Diode Low Leakage	NS	FD300	280300
CR28	Diode Switching	NS	1N4149	234149
CR29	Diode Switching	NS	1N4149	234149
CR51	Diode Switching	NS	1N4149	234149
CR53	Diode Switching	NS	1N4149	234149
CR68	Diode Switching	NS	1N4149	234149
CR69	Diode Switching	NS	1N4149	234149
CR76	Diode Switching	NS	1N4149	234149
CR78	Diode Switching	NS	1N4149	234149
CR87	Diode Switching	NS	1N4149	234149
CR88	Diode Switching	NS	1N4149	234149
CR100	Diode Switching	NS	1N4149	234149
CR103	Diode Switching	NS	1N4149	234149
CR104	Diode Switching	NS	1N4149	234149
CR108	Diode Switching	NS	1N4149	234149
CR119	Diode Switching	NS	1N4149	234149
CR120	Diode Switching	NS	1N4149	234149
CR121	Diode Switching	NS	1N4149	234149
CR122	Diode Switching	NS	1N4149	234149
CR123	Diode Switching	NS	1N4149	234149
CR124	Diode Switching	NS	1N4149	234149
CR125	Diode Switching	NS	1N4149	234149
CR162	Diode Switching	NS	1N4149	234149
CR167	Diode Switching	NS	1N4149	234149
CR168	Diode Switching	NS	1N4149	234149
CR170	Diode Switching	NS	1N4149	234149
CR180	Diode Switching	NS	1N4149	234149
CR181	Diode Switching	NS	1N4149	234149
CR186	Diode Switching	NS	1N4149	234149
CR187	Diode Switching	NS	1N4149	234149
CR188	Diode Switching	NS	1N4149	234149
CR196	Diode Switching	NS	1N4149	234149
CR205	Diode Hot Carrier	TOM	1N6263	286263
CR321	Diode Low Leakage	NS	FD300	280300
CR326	Diode Low Leakage	NS	FD300	280300
CR328	Diode Switching	NS	1N4149	234149
CR329	Diode Switching	NS	1N4149	234149
CR351	Diode Switching	NS	1N4149	234149
CR353	Diode Switching	NS	1N4149	234149
CR368	Diode Switching	NS	1N4149	234149
CR369	Diode Switching	NS	1N4149	234149
CR376	Diode Switching	NS	1N4149	234149

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
CR378	Diode Switching	NS	1N4149	234149
CR387	Diode Switching	NS	1N4149	234149
CR388	Diode Switching	NS	1N4149	234149
CR400	Diode Switching	NS	1N4149	234149
CR403	Diode Switching	NS	1N4149	234149
CR404	Diode Switching	NS	1N4149	234149
CR408	Diode Switching	NS	1N4149	234149
CR419	Diode Switching	NS	1N4149	234149
CR420	Diode Switching	NS	1N4149	234149
CR421	Diode Switching	NS	1N4149	234149
CR422	Diode Switching	NS	1N4149	234149
CR423	Diode Switching	NS	1N4149	234149
CR424	Diode Switching	NS	1N4149	234149
CR425	Diode Switching	NS	1N4149	234149
CR462	Diode Switching	NS	1N4149	234149
CR467	Diode Switching	NS	1N4149	234149
CR468	Diode Switching	NS	1N4149	234149
CR470	Diode Switching	NS	1N4149	234149
CR480	Diode Switching	NS	1N4149	234149
CR481	Diode Switching	NS	1N4149	234149
CR486	Diode Switching	NS	1N4149	234149
CR487	Diode Switching	NS	1N4149	234149
CR488	Diode Switching	NS	1N4149	234149
CR496	Diode Switching	NS	1N4149	234149
CR505	Diode Hot Carrier	TOM	1N6263	286263
CR618	Diode Hot Carrier	TOM	1N6263	286263
CR625	Diode Switching	NS	1N4149	234149
CR688	Diode Hot Carrier	TOM	1N6263	286263
CR689	Diode Hot Carrier	TOM	1N6263	286263
CR690	Diode Hot Carrier	TOM	1N6263	286263
CR691	Diode Hot Carrier	TOM	1N6263	286263
CR724	Diode Switching	NS	1N4149	234149
CR725	Diode Switching	NS	1N4149	234149
CR726	Diode Switching	NS	1N4149	234149
CR733	Diode Switching	NS	1N4149	234149
CR1006	Diode Switching	NS	1N4149	234149
CR1015	Diode Switching	NS	1N4149	234149
CR1050	Diode Rectifier	DI	1N4002	244002
CR1051	Diode Rectifier	DI	1N4002	244002
CR1052	Diode Rectifier	DI	1N4002	244002
CR1053	Diode Rectifier	DI	1N4002	244002
CR1060	Diode Switching	MOT	MR501	200500
CR1061	Diode Switching	MOT	MR501	200500
CR1062	Diode Switching	MOT	MR501	200500
CR1063	Diode Switching	MOT	MR501	200500
CR1108	Diode Switching	NS	1N4149	234149
CR1109	Diode Switching	NS	1N4149	234149
CR1110	Diode Switching	NS	1N4149	234149
CR1111	Diode Switching	NS	1N4149	234149
CR1112	Diode Switching	NS	1N4149	234149
CR1113	Diode Switching	NS	1N4149	234149
CR1114	Diode Switching	NS	1N4149	234149
CR1115	Diode Switching	NS	1N4149	234149
DS1	Lamp 120V .025A	SYL	120PS	012002
DS301	Lamp 120V .025A	SYL	120PS	012002

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
DS1100	Led Yellow	ROM	SLR34Y3	290343Y
DS1101	Led Red	ROM	SLR34VR3	290343
DS1102	Led Red	ROM	SLR34VR3	290343
DS1103	Led Green	ROM	SLR34MG3	290343G
DS1104	Led Green	ROM	SLR34MG3	290343G
DS1105	Led Green	ROM	SLR34MG3	290343G
DS1108	Led Red	ROM	SLR34VR3	290343
DS1109	Led Red	ROM	SLR34VR3	290343
DS1110	Led Green	ROM	SLR34MG3	290343G
DS1111	Led Green	ROM	SLR34MG3	290343G
DS1112	Led Green	ROM	SLR34MG3	290343G
F1050	Fuse Slow Blow	BUS	MDL 3/4A	021011
J1	Connector BNC	APH	31-010	370402
J100	Connector 10-Pin Male	MLX	39-26-7105	015038
J301	Connector BNC	APH	31-010	370402
J400	Connector 10-Pin Male	MLX	39-26-7105	015038
J600	Connector 26-Pin Male	MLX	39-26-7265	015039
J680	Connector 10-Pin Male	MLX	39-26-7105	015038
J736	Connector BNC	APH	31-010	370402
J1004	Connector 26-Pin Male	MLX	39-26-7265	015039
J1005	Connector 16-Pin Male	MLX	39-26-7165	015052
J1010	Connector 10-Pin Male	MLX	39-26-7105	015038
J1015	Connector 10-Pin Male	MLX	39-26-7105	015038
J1020	Connector 26-Pin Male	MLX	39-26-7265	015039
J1051	Connector 9-Pin Male	MLX	09-64-1091	015030
J1100	Connector 16-Pin Male	MLX	39-26-7165	015052
J1101	Connector 10-Pin Male	MLX	39-26-7105	015038
K123	Relay SPST Reed	KH	B4172-1	029024
K124	Relay SPST 400V	KH	B4489-1	029028
K125	Relay SPST Reed	KH	B4172-1	029024
K126	Relay SPST 400V	KH	B4489-1	029028
K127	Relay SPST Reed	KH	B4172-1	029024
K128	Relay SPST 500V	KH	B4489-2	029027
K129	Relay SPDT Reed	KH	B4172-3	029026
K130	Relay SPST Reed	KH	B4172-1	029024
K131	Relay SPDT Reed	KH	B4172-3	029026
K132	Relay SPST Reed	KH	B4172-1	029024
K135	Relay SPST Reed	KH	B4172-1	029024
K136	Relay SPST Reed	KH	B4172-1	029024
K423	Relay SPST Reed	KH	B4172-1	029024
K424	Relay SPST 400V	KH	B4489-1	029028
K425	Relay SPST Reed	KH	B4172-1	029024
K426	Relay SPST 400V	KH	B4489-1	029028
K427	Relay SPST Reed	KH	B4172-1	029024
K428	Relay SPST 500V	KH	B4489-2	029027
K429	Relay SPDT Reed	KH	B4172-3	029026
K430	Relay SPST Reed	KH	B4172-1	029024
K431	Relay SPDT Reed	KH	B4172-3	029026
K432	Relay SPST Reed	KH	B4172-1	029024
K435	Relay SPST Reed	KH	B4172-1	029024
K436	Relay SPST Reed	KH	B4172-1	029024
K692	Relay SPDT Reed	KH	B4172-3	029026
K706	Relay SPDT Reed	KH	B4172-3	029026
K1015	Relay SPDT Reed	KH	B4172-3	029026

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
L48	Choke 22uH 10% 1/4W	DLV	1537-44	001009
L135	Choke 22uH 10% 1/4W	DLV	1537-44	001009
L166	Choke 3.3uH 10% 1/4W	DLV	1537-24	001004
L187	Choke 22uH 10% 1/4W	DLV	1537-44	001009
L348	Choke 22uH 10% 1/4W	DLV	1537-44	001009
L435	Choke 22uH 10% 1/4W	DLV	1537-44	001009
L466	Choke 3.3uH 10% 1/4W	DLV	1537-24	001004
L487	Choke 22uH 10% 1/4W	DLV	1537-44	001009
Q26	Transistor PNP	MOT	2N3906	203906
Q30	Transistor FET	SLX	U441	260421
Q31	Transistor NPN	MOT	2N2917	202917
Q36	Transistor NPN	MOT	MPS6515	206515
Q47	Transistor PNP	MOT	2N5771	204258
Q48	Transistor NPN	MOT	MPS2369	202369
Q51	Transistor NPN	MOT	2N3904	203904
Q53	Transistor PNP	MOT	2N3906	203906
Q76	Transistor NPN	MOT	MPS6515	206515
Q86	Transistor PNP	MOT	2N3906	203906
Q90	Transistor NPN	MOT	MPS6515	206515
Q91	Transistor NPN	MOT	MPS6515	206515
Q100	Transistor NPN	MOT	MPS6515	206515
Q105	Transistor PNP	MOT	2N3906	203906
Q111	Transistor NPN	MOT	MPS6515	206515
Q116	Transistor PNP	MOT	2N3906	203906
Q117	Transistor NPN	MOT	2N3904	203904
Q118	Transistor NPN	MOT	2N3904	203904
Q146	Transistor NPN	MOT	MPS6515	206515
Q147	Transistor PNP	MOT	2N3906	203906
Q153	Transistor NPN	MOT	2N2917	202917
Q165	Transistor NPN	MOT	MPS2369	202369
Q167	Transistor PNP	MOT	2N5771	204258
Q168	Transistor NPN	MOT	2N3904	203904
Q170	Transistor PNP	MOT	2N3906	203906
Q199	Transistor FET	MOT	MPF4392	204392
Q201	Transistor NPN	MOT	MPS6515	206515
Q202	Transistor NPN	MOT	MPS2369	202369
Q205	Transistor PNP	MOT	MPS3640	203640
Q231	Transistor PNP	MOT	2N5771	204258
Q233	Transistor PNP	MOT	2N5771	204258
Q326	Transistor PNP	MOT	2N3906	203906
Q330	Transistor FET	SLX	U441	260421
Q331	Transistor NPN	MOT	2N2917	202917
Q336	Transistor NPN	MOT	MPS6515	206515
Q347	Transistor PNP	MOT	2N5771	204258
Q348	Transistor NPN	MOT	MPS2369	202369
Q351	Transistor NPN	MOT	2N3904	203904
Q353	Transistor PNP	MOT	2N3906	203906
Q376	Transistor NPN	MOT	MPS6515	206515
Q386	Transistor PNP	MOT	2N3906	203906
Q390	Transistor NPN	MOT	MPS6515	206515
Q391	Transistor NPN	MOT	MPS6515	206515
Q400	Transistor NPN	MOT	MPS6515	206515
Q405	Transistor PNP	MOT	2N3906	203906
Q411	Transistor NPN	MOT	MPS6515	206515
Q416	Transistor PNP	MOT	2N3906	203906

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
Q417	Transistor NPN	MOT	2N3904	203904
Q418	Transistor NPN	MOT	2N3904	203904
Q446	Transistor NPN	MOT	MPS6515	206515
Q447	Transistor PNP	MOT	2N3906	203906
Q453	Transistor NPN	MOT	2N2917	202917
Q465	Transistor NPN	MOT	MPS2369	202369
Q467	Transistor PNP	MOT	2N5771	204258
Q468	Transistor NPN	MOT	2N3904	203904
Q470	Transistor PNP	MOT	2N3906	203906
Q483	Transistor PNP	MOT	2N3906	203906
Q499	Transistor FET	MOT	MPF4392	204392
Q501	Transistor NPN	MOT	MPS6515	206515
Q502	Transistor NPN	MOT	MPS2369	202369
Q505	Transistor PNP	MOT	MPS3640	203640
Q531	Transistor PNP	MOT	2N5771	204258
Q533	Transistor PNP	MOT	2N5771	204258
Q600	Transistor PNP	MOT	2N3906	203906
Q604	Transistor NPN	MOT	MPS2369	202369
Q605	Transistor NPN	MOT	MPS2369	202369
Q608	Transistor NPN	MOT	MPS2369	202369
Q618	Transistor PNP	MOT	MPS3640	203640
Q620	Transistor PNP	MOT	2N3906	203906
Q623	Transistor NPN	MOT	MPS2369	202369
Q625	Transistor NPN	MOT	MPS6515	206515
Q632	Transistor NPN	MOT	MPS6515	206515
Q661	Transistor PNP	MOT	MPS3640	203640
Q663	Transistor PNP	MOT	MPS3640	203640
Q665	Transistor PNP	MOT	MPS3640	203640
Q667	Transistor PNP	MOT	MPS3640	203640
Q675	Transistor NPN	MOT	MPS6515	206515
Q678	Transistor PNP	MOT	2N3906	203906
Q679	Transistor PNP	MOT	2N3906	203906
Q686	Transistor FET	MOT	MPF4392	204392
Q692	Transistor PNP	MOT	2N3906	203906
Q720	Transistor NPN	MOT	MPS6515	206515
Q722	Transistor PNP	MOT	2N3906	203906
Q724	Transistor FET	MOT	MPF4392	204392
Q725	Transistor FET	MOT	MPF4392	204392
Q731	Transistor FET	MOT	MPF4392	204392
Q732	Transistor FET	MOT	2N4340	214340
Q734	Transistor NPN	MOT	MPS6515	206515
Q1002	Transistor NPN	MOT	MPS6515	206515
Q1003	Transistor NPN	MOT	MPS6515	206515
Q1010	Transistor PNP	MOT	2N3906	203906
Q1015	Transistor PNP	MOT	2N4265	204265
Q1100	Transistor PNP	MOT	MPS-A55	220093
Q1101	Transistor PNP	MOT	MPS-A55	220093
Q1102	Transistor PNP	MOT	MPS-A55	220093
Q1103	Transistor PNP	MOT	MPS-A55	220093
Q1104	Transistor PNP	MOT	MPS-A55	220093
Q1105	Transistor PNP	MOT	MPS-A55	220093
Q1106	Transistor PNP	MOT	MPS-A55	220093
Q1107	Transistor PNP	MOT	MPS-A55	220093
Q1108	Transistor PNP	MOT	MPS-A55	220093
Q1109	Transistor PNP	MOT	MPS-A55	220093

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
Q1110	Transistor PNP	MOT	MPS-A55	220093
Q1111	Transistor PNP	MOT	MPS-A55	220093
Q1112	Transistor PNP	MOT	MPS-A55	220093
Q1113	Transistor PNP	MOT	MPS-A55	220093
Q1114	Transistor PNP	MOT	MPS-A55	220093
Q1115	Transistor PNP	MOT	MPS-A55	220093
R1	10M 10% 1/4W	AB	CB1061	928610
R2	1M 1% 1/4W	MEP	RN60D-NA60	825511
R3	6.81K 1% 1/4W	MEP	5043	927268
R4	1K 10% Pot	BKM	72PMR1K	658210
R5	1.5K 1% 1/4W	MEP	5043	927215
R6	1.5M 1% 1/4W	MEP	5043	928515
R7	182 1% 1/4W	MEP	5043	927118
R8	Trim			———
R9	124K 1% 1/2W	PRP	RN60D-NA60	825413
R10	1M 1% 1/4W	MEP	RN60D-NA60	825511
R13	100M 10% 1/4W	AB	EB1071	928710
R14	1M 1% 1/4W	MEP	RN60D-NA60	825511
R15	1K 10% Pot	BKM	72PMR1K	658210
R16	2.43K 1% 1/4W	MEP	5043	927224
R17	392K 1% 1/4W	MEP	5043	927439
R18	22.1 1% 1/4W	MEP	5043	928022
R19	5.1M 5% 1/4W	AB	CB5G165	927551
R20	9.31K 1% 1/2W	MEP	RN60D-NA60	825293
R21	1.5M 1% 1/4W	MEP	5043	928482
R22	953 1% 1/2W	MEP	RN60D-NA60	825209
R25	26.7K 1% 1/4W	MEP	5043	928327
R26	1.3K 1% 1/4W	MEP	5043	927213
R27	100 1% 1/4W	MEP	5043	927110
R28	1.			927243
R35	16.2K 1% 1/4W	MEP	5043	927316
R36	1.3K 1% 1/4W	MEP	5043	927213
R37	100 1% 1/4W	MEP	5043	927110
R38	113 1% 1/4W	MEP	5043	850111
R39	10 1% 1/4W	MEP	5043	850010
R40	4.99K 1% 1/4W	MEP	5043	850249
R41	562 1% 1/4W	MEP	5043	927156
R42	56.2 1% 1/4W	MEP	5043	928056
R43	511 1% 1/4W	MEP	5043	927151
R44	499 1% 1/4W	MEP	5043	850149
R45	49.9 1% 1/4W	MEP	5043	850049
R46	267 1% 1/4W	MEP	5043	928127
R47	100 1% 1/4W	MEP	5043	927110
R48	1K 1% 1/4W	MEP	5043	927210
R49	10 1% 1/4W	MEP	5043	850010
R50	100 1% 1/4W	MEP	5043	927110
R51	10 1% 1/4W	MEP	5043	850010
R52	49.9 1% 1/4W	MEP	5043	850049
R53	10 1% 1/4W	MEP	5043	850010
R54	1.5K 1% 1/4W	MEP	5043	927215
R55	10 1% 1/4W	MEP	5043	850010
R56	100 1% 1/4W	MEP	5043	927110
R57	1.00K 1% 1/4W	MEP	5043	927210
R64	1K 1% 1/4W	MEP	5043	927210
R65	221 1% 1/4W	MEP	5043	928122

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R66	681K 1% 1/4W	MEP	5043	927468
R67	1K 10% Pot	BKM	72PMR1K	658210
R68	825 1% 1/4W	MEP	5043	927182
R69	51.1K 1% 1/4W	MEP	5043	927351
R70	1.5M 10% 1/4W	PRP	GP1/4W-T100	928515
R71	22.1K 1% 1/4W	MEP	5043	927322
R72	221 1% 1/4W	MEP	5043	928122
R73	100K 1% 1/4W	MEP	5043	927410
R74	100 1% 1/4W	MEP	5043	927110
R75	3.32K 1% 1/4W	MEP	5043	927233
R76	200K 1% 1/4W	MEP	5043	927420
R77	1K 1% 1/4W	MEP	5043	927210
R78	56.2K 1% 1/4W	MEP	5043	927356
R79	130K 1% 1/4W	MEP	5043	927413
R80	15.0K 1% 1/4W	MEP	5043	927315
R81	5.49M 1% 1/4W	MEP	5043	850554
R82	5.49M 1% 1/4W	MEP	5043	850554
R83	100K 10% Pot	BKM	72PMR100K	658410
R84	5.11K 1% 1/4W	MEP	5043	927251
R85	10K 10% Pot	BKM	72PMR10K	658310
R86	10K 1% 1/4W	MEP	5043	927310
R87	681K 1% 1/4W	MEP	5043	927468
R88	5.1M 5% 1/4W	AB	CB5G165	927551
R89	1M 10% Pot	BKM	72PMR1M	658510
R90	10K 1% 1/4W	MEP	5043	927310
R91	4.75K 1% 1/4W	MEP	5043	927247
R100	4.75K 1% 1/4W	MEP	5043	927247
R101	10K 1% 1/4W	MEP	5043	927310
R102	4.75K 1% 1/4W	MEP	5043	927247
R103	10K 1% 1/4W	MEP	5043	927310
R104	22.1K 1% 1/4W	MEP	5043	927322
R105	4.75K 1% 1/4W	MEP	5043	927247
R106	4.75K 1% 1/4W	MEP	5043	927247
R107	3.32K 1% 1/4W	MEP	5043	927233
R108	332K 1% 1/4W	MEP	5043	928433
R110	10K 1% 1/4W	MEP	5043	927310
R111	3.57K 1% 1/4W	MEP	5043	927236
R112	4.75K 1% 1/4W	MEP	5043	927247
R113	4.75K 1% 1/4W	MEP	5043	927247
R114	4.75K 1% 1/4W	MEP	5043	927247
R115	4.75K 1% 1/4W	MEP	5043	927247
R116	4.75K 1% 1/4W	MEP	5043	927247
R117	4.75K 1% 1/4W	MEP	5043	927247
R118	4.75K 1% 1/4W	MEP	5043	927247
R119	4.75K 1% 1/4W	MEP	5043	927247
R120	4.75K 1% 1/4W	MEP	5043	927247
R140	15K 1% 1/4W	MEP	5043	927315
R141	15K 1% 1/4W	MEP	5043	927315
R142	16.2K 1% 1/4W	MEP	5043	927316
R143	562 1% 1/4W	MEP	5043	927156
R144	562 1% 1/4W	MEP	5043	927156
R145	16.2K 1% 1/4W	MEP	5043	927316
R146	10 1% 1/4W	MEP	5043	850010
R147	10 1% 1/4W	MEP	5043	850010
R148	200 1% 1/4W	MEP	5043	927120
R149	26.7 1% 1/4W	MEP	5043	928027

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R150	75 1% 1/4W	MEP	5043	927075
R152	332 1% 1/4W	MEP	5043	927133
R153	4.7 5% 1/4W	AB	CB47G1	928947
R154	100 25 Turn Pot	BOU	3299W-1-101	689110
R155	1.43K 1% 1/4W	MEP	5043	850214
R156	511 1% 1/4W	MEP	5043	927151
R157	16.2K 1% 1/4W	MEP	5043	927316
R158	511 1% 1/4W	MEP	5043	927151
R159	200 1% 1/4W	MEP	5043	927120
R160	2.74K 1% 1/4W	MEP	5043	850227
R161	1.5K 1% 1/4W	MEP	5043	927215
R162	1.5K 1% 1/4W	MEP	5043	927215
R163	10 1% 1/4W	MEP	5043	850010
R164	100 1% 1/4W	MEP	5043	927215
R172	10 1% 1/4W	MEP	5043	850010
R173	100 1% 1/4W	MEP	5043	927110
R174	18.2K 1% 1/4W	MEP	5043	927318
R175	Trim			———
R176	Trim			———
R177	8.2K 1% 1/4W	MEP	5043	927282
R180	1.1K 1% 1/4W	MEP	5043	927211
R181	10K 1% 1/4W	MEP	5043	927310
R182	22.1K 1% 1/4W	MEP	5043	927322
R186	1.1K 1% 1/4W	MEP	5043	927211
R187	1K 1% 1/4W	MEP	5043	927210
R188	20K 1% 1/4W	MEP	5043	927320
R189	330 10% 1/2W	PRP	GP1/2W-T100	938133
R195	10 1% 1/4W	MEP	5043	850010
R196	4.75K 1% 1/4W	MEP	5043	927247
R197	10 1% 1/4W	MEP	5043	850010
R198	182K 1% 1/4W	MEP	5043	928418
R199	10K 1% 1/4W	MEP	5043	927310
R200	10 1% 1/4W	MEP	5043	850010
R201	3.32K 1% 1/4W	MEP	5043	927233
R202	10K 1% 1/4W	MEP	5043	927310
R203	1K 1% 1/4W	MEP	5043	927210
R204	1K 1% 1/4W	MEP	5043	927210
R205	2.21K 1% 1/4W	MEP	5043	927222
R206	1K 1% 1/4W	MEP	5043	927210
R207	4.87K 1% 1/4W	MEP	5043	850248
R210	1.6M 1% 1/4W	AB	CB1G665	927516
R211	10K 10% Pot	BKM	72PMR10K	658310
R212	13.3K 0.1% 1/4W	PRP	GP1/4W-T100	820313
R215	10 1% 1/4W	MEP	5043	928010
R216	4.32K 1% 1/4W	MEP	5043	927243
R217	332 1% 1/4W	MEP	5043	927133
R218	4.32K 1% 1/4W	MEP	5043	927243
R219	332 1% 1/4W	MEP	5043	927133
R220	13.3K 0.1% 1/4W	PRP	GP1/4W-T100	820313
R221	4.87K 1% 1/4W	MEP	5043	850248
R222	16.2K 1% 1/4W	MEP	5043	927316
R223	3.48K 1% 1/4W	MEP	5043	850234
R224	6.65K 0.1% 1/4W	PRP	GP1/4W-T100	820266

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R225	24.9K 1% 1/4W	MEP	5043	850324
R226	24.9K 1% 1/4W	MEP	5043	850324
R227	3.48K 1% 1/4W	MEP	5043	850234
R228	6.65K 0.1% 1/4W	PRP	GP1/4W-T100	820266
R229	200 1% 1/4W	MEP	5043	927120
R230	2.21K 1% 1/4W	MEP	5043	927222
R231	100 1% 1/4W	MEP	5043	927110
R232	825 1% 1/4W	MEP	5043	927182
R233	100 1% 1/4W	MEP	5043	927110
R234	243 1% 1/4W	MEP	5043	927124
R235	1.3K 1% 1/4W	MEP	5043	927213
R236	619 1% 1/4W	MEP	5043	927162
R301	10M 10% 1/4W	AB	CB1061	928610
R302	1M 1% 1/4W	MEP	RN60D-NA60	825511
R303	6.81K 1% 1/4W	MEP	5043	927268
R304	1K 10% Pot	BKM	72PMR1K	658210
R305	1.5K 1% 1/4W	MEP	5043	927215
R306	1.5M 1% 1/4W	MEP	5043	928515
R307	182 1% 1/4W	MEP	5043	927118
R308	Trim			——
R309	124K 1% 1/2W	MEP	RN60D-NA60	825413
R310	1M 1% 1/4W	MEP	RN60D-NA60	825511
R313	100M 10% 1/4W	AB	EB1071	928710
R314	1M 1% 1/4W	MEP	RN60D-NA60	825511
R315	1K 10% Pot	BKM	72PMR1K	658210
R316	2.43K 1% 1/4W	MEP	5043	927224
R317	392K 1% 1/4W	MEP	5043	927439
R318	22.1 1% 1/4W	MEP	5043	928022
R319	5.1M 5% 1/4W	AB	CB5G165	927551
R320	9.31K 1% 1/2W	MEP	RN60D-NA60	825293
R321	1.5M 1% 1/4W	MEP	5043	928482
R322	953 1% 1/2W	MEP	RN60D-NA60	825209
R325	26.7K 1% 1/4W	MEP	5043	928327
R326	1.3K 1% 1/4W	MEP	5043	927213
R327	100 1% 1/4W	MEP	5043	927110
R328	1.5K 1% 1/4W	MEP	5043	927215
R329	1.5K 1% 1/4W	MEP	5043	927215
R330	332 1% 1/4W	MEP	5043	927133
R331	4.7 5% 1/4W	AB	CB47G1	928947
R332	10 10% Pot	BKM	72XWR10	658011
R333	332 1% 1/4W	MEP	5043	927133
R334	4.32K 1% 1/4W	MEP	5043	927243
R335	16.2K 1% 1/4W	MEP	5043	927316
R336	1.3K 1% 1/4W	MEP	5043	927213
R337	100 1% 1/4W	MEP	5043	927110
R338	113 1% 1/4W	MEP	5043	850111
R339	10 1% 1/4W	MEP	5043	850010
R340	4.99K 1% 1/4W	MEP	5043	850249
R341	562 1% 1/4W	MEP	5043	927156
R342	56.2 1% 1/4W	MEP	5043	928056
R343	511 1% 1/4W	MEP	5043	927151
R344	499 1% 1/4W	MEP	5043	850149
R345	49.9 1% 1/4W	MEP	5043	850049
R346	267 1% 1/4W	MEP	5043	928127
R347	100 1% 1/4W	MEP	5043	927110

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R348	1K 1% 1/4W	MEP	5043	927210
R349	10 1% 1/4W	MEP	5043	850010
R350	100 1% 1/4W	MEP	5043	927110
R351	10 1% 1/4W	MEP	5043	850010
R352	49.9 1% 1/4W	MEP	5043	850049
R353	10 1% 1/4W	MEP	5043	850010
R354	1.5K 1% 1/4W	MEP	5043	927215
R355	10 1% 1/4W	MEP	5043	850010
R356	100 1% 1/4W	MEP	5043	927110
R364	1K 1% 1/4W	MEP	5043	927210
R365	221 1% 1/4W	MEP	5043	928122
R366	681K 1% 1/4W	MEP	5043	927468
R367	1K 10% Pot	BKM	72PMR1K	658210
R368	825 1% 1/4W	MEP	5043	927182
R369	51.1K 1% 1/4W	MEP	5043	927351
R370	1.5M 10% 1/4W	PRP	GP1/4W-T100	928515
R371	22.1K 1% 1/4W	MEP	5043	850321
R372	221 1% 1/4W	MEP	5043	928122
R373	100K 1% 1/4W	MEP	5043	927410
R374	100 1% 1/4W	MEP	5043	927110
R375	3.32K 1% 1/4W	MEP	5043	927233
R376	200K 1% 1/4W	MEP	5043	927420
R377	1K 1% 1/4W	MEP	5043	927210
R378	56.2K 1% 1/4W	MEP	5043	927356
R379	130K 1% 1/4W	MEP	5043	927413
R380	16.2K 1% 1/4W	MEP	5043	927316
R381	5.49M 1% 1/4W	MEP	5043	850554
R382	5.49M 1% 1/4W	MEP	5043	850554
R383	100K 10% Pot	BKM	72PMR100K	658410
R384	5.11K 1% 1/4W	MEP	5043	927251
R385	10K 10% Pot	BKM	72PMR10K	658310
R386	10K 1% 1/4W	MEP	5043	927310
R387	681K 1% 1/4W	MEP	5043	927468
R388	5.1M 5% 1/4W	AB	CB5G165	927551
R389	1M 10% Pot	BKM	72PMR1M	658510
R390	10K 1% 1/4W	MEP	5043	927310
R391	4.75K 1% 1/4W	MEP	5043	927247
R400	4.75K 1% 1/4W	MEP	5043	927247
R401	10K 1% 1/4W	MEP	5043	927310
R402	4.75K 1% 1/4W	MEP	5043	927247
R403	10K 1% 1/4W	MEP	5043	927310
R404	22.1K 1% 1/4W	MEP	5043	927322
R405	4.75K 1% 1/4W	MEP	5043	927247
R406	4.75K 1% 1/4W	MEP	5043	927247
R407	3.32K 1% 1/4W	MEP	5043	927233
R408	332K 1% 1/4W	MEP	5043	928433
R410	10K 1% 1/4W	MEP	5043	927310
R411	3.57K 1% 1/4W	MEP	5043	927236
R412	4.75K 1% 1/4W	MEP	5043	927247
R413	4.75K 1% 1/4W	MEP	5043	927247
R414	4.75K 1% 1/4W	MEP	5043	927247
R415	4.75K 1% 1/4W	MEP	5043	927247
R416	4.75K 1% 1/4W	MEP	5043	927247
R417	4.75K 1% 1/4W	MEP	5043	927247
R418	4.75K 1% 1/4W	MEP	5043	927247

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R419	4.75K 1% 1/4W	MEP	5043	927247
R420	4.75K 1% 1/4W	MEP	5043	927247
R440	15K 1% 1/4W	MEP	5043	927315
R441	15K 1% 1/4W	MEP	5043	927315
R442	16.2K 1% 1/4W	MEP	5043	927316
R443	562 1% 1/4W	MEP	5043	927156
R444	562 1% 1/4W	MEP	5043	927156
R445	16.2K 1% 1/4W	MEP	5043	927316
R446	10 1% 1/4W	MEP	5043	850010
R447	10 1% 1/4W	MEP	5043	850010
R448	200 1% 1/4W	MEP	5043	927120
R449	26.7 1% 1/4W	MEP	5043	928027
R450	75 1% 1/4W	MEP	5043	927075
R452	332 1% 1/4W	MEP	5043	927133
R453	4.7 5% 1/4W	AB	CB47G1	928947
R454	100 25 Turn Pot	BOU	3299W-1-101	689110
R455	1.43K 1% 1/4W	MEP	5043	850214
R456	511 1% 1/4W	MEP	5043	927151
R457	16.2K 1% 1/4W	MEP	5043	927316
R458	511 1% 1/4W	MEP	5043	927151
R459	200 1% 1/4W	MEP	5043	927120
R460	2.74K 1% 1/4W	MEP	5043	850227
R461	1.5K 1% 1/4W	MEP	5043	927215
R462	1.5K 1% 1/4W	MEP	5043	927215
R463	10 1% 1/4W	MEP	5043	850010
R464	100 1% 1/4W	MEP	5043	927110
R465	4.7 5% 1/4W	AB	CB47G1	928947
R466	221 1% 1/4W	MEP	5043	928122
R467	100 1% 1/4W	MEP	5043	927110
R468	10 1% 1/4W	MEP	5043	850010
R469	49.9 1% 1/4W	MEP	5043	850049
R470	10 1% 1/4W	MEP	5043	850010
R471	1.5K 1% 1/4W	MEP	5043	927215
R472	10 1% 1/4W	MEP	5043	850010
R473	100 1% 1/4W	MEP	5043	927110
R474	18.2K 1% 1/4W	MEP	5043	927318
R475	Trim			———
R477	8.2K 1% 1/4W	MEP	5043	927282
R480	1.1K 1% 1/4W	MEP	5043	927211
R481	10K 1% 1/4W	MEP	5043	927310
R482	22.1K 1% 1/4W	MEP	5043	927322
R483	10K 1% 1/4W	MEP	5043	927310
R484	10K 1% 1/4W	MEP	5043	927310
R485	1.82K 1% 1/4W	MEP	5043	927218
R486	1.1K 1% 1/4W	MEP	5043	927211
R487	1K 1% 1/4W	MEP	5043	927210
R488	20K 1% 1/4W	MEP	5043	927320
R489	330 10% 1/2W	PRP	GP1/2W-T100	938133
R495	10 1% 1/4W	MEP	5043	850010
R496	4.75K 1% 1/4W	MEP	5043	927247
R497	10 1% 1/4W	MEP	5043	850010
R498	182K 1% 1/4W	MEP	5043	928418
R500	10 1% 1/4W	MEP	5043	850010
R501	3.32K 1% 1/4W	MEP	5043	927233
R502	10K 1% 1/4W	MEP	5043	927310

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R503	1K 1% 1/4W	MEP	5043	927210
R504	1K 1% 1/4W	MEP	5043	927210
R505	2.21K 1% 1/4W	MEP	5043	927222
R506	1K 1% 1/4W	MEP	5043	927210
R507	4.87K 1% 1/4W	MEP	5043	850248
R510	1.6M 1% 1/4W	AB	CB1G665	927516
R511	10K 10% Pot	BKM	72PMR10K	658310
R512	13.3K 0.1% 1/4W	PRP	GP1/4W-T100	820313
R515	10 1% 1/4W	MEP	5043	928010
R516	4.32K 1% 1/4W	MEP	5043	927243
R517	332 1% 1/4W	MEP	5043	927133
R518	4.32K 1% 1/4W	MEP	5043	927243
R519	332 1% 1/4W	MEP	5043	927133
R520	13.3K 0.1% 1/4W	PRP	GP1/4W-T100	820313
R521	4.87K 1% 1/4W	MEP	5043	850248
R523	3.48K 1% 1/4W	MEP	5043	850234
R524	6.65K 0.1% 1/4W	PRP	GP1/4W-T100	820266
R525	24.9K 1% 1/4W	MEP	5043	850324
R526	24.9K 1% 1/4W	MEP	5043	850324
R527	3.48K 1% 1/4W	MEP	5043	850234
R528	6.65K 0.1% 1/4W	PRP	GP1/4W-T100	820266
R529	200 1% 1/4W	MEP	5043	927120
R530	2.21K 1% 1/4W	MEP	5043	927222
R531	100 1% 1/4W	MEP	5043	927110
R532	825 1% 1/4W	MEP	5043	927182
R533	100 1% 1/4W	MEP	5043	927110
R599	10K 1% 1/4W	MEP	5043	927310
R600	221 1% 1/4W	MEP	5043	928122
R601	3.32K 1% 1/4W	MEP	5043	927233
R602	1.62K 1% 1/4W	MEP	5043	927216
R603	9.09K 1% 1/4W	MEP	5043	850290
R604	2.67K 1% 1/4W	MEP	5043	927227
R605	1K 1% 1/4W	MEP	5043	927210
R606	1K 1% 1/4W	MEP	5043	927210
R607	1K 1% 1/4W	MEP	5043	927210
R608	2.67K 1% 1/4W	MEP	5043	927227
R609	511 1% 1/4W	MEP	5043	927151
R610	221 1% 1/4W	MEP	5043	928122
R611	8.2K 1% 1/4W	MEP	5043	927282
R612	51.1K 1% 1/4W	MEP	5043	927351
R613	267K 1% 1/4W	MEP	5043	928427
R614	5.1M 5% 1/4W	AB	CB5G165	927551
R617	56.2K 1% 1/4W	MEP	5043	927356
R618	2.21K 1% 1/4W	MEP	5043	927222
R619	1K 1% 1/4W	MEP	5043	927210
R620	10K 1% 1/4W	MEP	5043	927310
R621	10K 1% 1/4W	MEP	5043	927310
R622	10K 1% 1/4W	MEP	5043	927310
R623	1K 1% 1/4W	MEP	5043	927210
R624	1K 1% 1/4W	MEP	5043	927210
R625	4.75K 1% 1/4W	MEP	5043	927247
R630	619 1% 1/4W	MEP	5043	927162
R631	243 1% 1/4W	MEP	5043	927124
R632	47.5 1% 1/4W	MEP	5043	927047
R633	3.32K 1% 1/4W	MEP	5043	927233

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R634	243 1% 1/4W	MEP	5043	927124
R635	619 1% 1/4W	MEP	5043	927162
R636	243 1% 1/4W	MEP	5043	927124
R637	619 1% 1/4W	MEP	5043	927162
R638	243 1% 1/4W	MEP	5043	927124
R639	619 1% 1/4W	MEP	5043	927162
R640	243 1% 1/4W	MEP	5043	927124
R641	619 1% 1/4W	MEP	5043	927162
R642	243 1% 1/4W	MEP	5043	927124
R643	619 1% 1/4W	MEP	5043	927162
R645	511 1% 1/4W	MEP	5043	927151
R646	511 1% 1/4W	MEP	5043	927151
R647	511 1% 1/4W	MEP	5043	927151
R648	511 1% 1/4W	MEP	5043	927151
R649	511 1% 1/4W	MEP	5043	927151
R650	511 1% 1/4W	MEP	5043	927151
R651	511 1% 1/4W	MEP	5043	927151
R652	619 1% 1/4W	MEP	5043	927162
R653	2K 1% 1/4W	MEP	5043	927220
R654	511 1% 1/4W	MEP	5043	927151
R655	511 1% 1/4W	MEP	5043	927151
R656	511 1% 1/4W	MEP	5043	927151
R657	511 1% 1/4W	MEP	5043	927151
R658	511 1% 1/4W	MEP	5043	927151
R659	511 1% 1/4W	MEP	5043	927151
R660	511 1% 1/4W	MEP	5043	927151
R661	1K 1% 1/4W	MEP	5043	927210
R662	511 1% 1/4W	MEP	5043	927151
R663	1K 1% 1/4W	MEP	5043	927210
R664	511 1% 1/4W	MEP	5043	927151
R665	243 1% 1/4W	MEP	5043	927124
R666	715 1% 1/4W	MEP	5043	850171
R667	243 1% 1/4W	MEP	5043	927124
R668	2.43K 1% 1/4W	MEP	5043	927224
R675	10K 1% 1/4W	MEP	5043	927310
R676	10K 1% 1/4W	MEP	5043	927310
R677	267 1% 1/4W	MEP	5043	928127
R678	1.3K 1% 1/4W	MEP	5043	927213
R679	22.1K 1% 1/4W	MEP	5043	927322
R680	10K 1% 1/4W	MEP	5043	927310
R681	11.3K 1% 1/4W	MEP	5043	850311
R682	1.21K 1% 1/4W	MEP	5043	927212
R684	Trim			——
R685	150K 1% 1/4W	MEP	5043	927415
R686	619 0.1% 1/10W	MEP	5043	820161
R687	619 0.1% 1/10W	MEP	5043	820161
R688	Trim			——
R689	200 1% 1/4W	MEP	5043	927120
R690	158 1% 1/4W	MEP	5043	850115
R691	1K 1% 1/4W	MEP	5043	927210
R692	1K 1% 1/4W	MEP	5043	927210
R693	6.81K 1% 1/4W	MEP	5043	927268
R694	Trim			——
R695	2.52K 0.1% 1/10W	PRP	GP1/4W-T100	820225
R696	392K 1% 1/4W	MEP	5043	928439

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R698	1.21K 1% 1/4W	MEP	5043	927212
R699	100K 10% Pot	BKM	72PMR100K	658410
R700	332K 1% 1/4W	MEP	5043	928433
R701	35.7K 1% 1/4W	MEP	5043	927336
R702	11K 1% 1/4W	MEP	5043	927311
R703	110K 1% 1/4W	MEP	5043	927411
R704	100K 10% Pot	BKM	72PMR100K	658410
R705	17.8K 1% 1/4W	MEP	5043	850317
R706	100K 10% Pot	BKM	72PMR100K	658410
R707	82.5K 1% 1/4W	MEP	5043	927382
R714	825 1% 1/4W	MEP	5043	927182
R715	619 0.1% 1/10W	MEP	5043	820161
R716	11K 1% 1/4W	MEP	5043	927311
R717	10 1% 1/4W	MEP	5043	928010
R719	5.1M 5% 1/4W	AB	CB5G165	927551
R720	10K 1% 1/4W	MEP	5043	927310
R721	1K 1% 1/4W	MEP	5043	927210
R722	100K 1% 1/4W	MEP	5043	927410
R723	100K 1% 1/4W	MEP	5043	927410
R724	1M 1% 1/4W	MEP	5043	927510
R725	1M 1% 1/4W	MEP	5043	927510
R726	619K 1% 1/4W	MEP	5043	927462
R727	1.62K 1% 1/4W	MEP	5043	927216
R728	174K 1% 1/4W	MEP	5043	850417
R729	3.32K 1% 1/4W	MEP	5043	927233
R730	10 1% 1/4W	MEP	5043	850010
R731	10K 1% 1/4W	MEP	5043	927310
R732	100K 1% 1/4W	MEP	5043	927410
R733	4.75K 1% 1/4W	MEP	5043	927247
R734	267 1% 1/4W	MEP	5043	928127
R735	1.82K 0.1% 1/4W	PRP	GP1/4W-T100	822218A
R736	49.9 1% 1/4W	MEP	5043	850049
R737	2M 1% 1/4W	AB	CB2G65	927520
R1000	3.32K 1% 1/4W	MEP	5043	927233
R1001	3.32K 1% 1/4W	MEP	5043	927233
R1002	2.67K 1% 1/4W	MEP	5043	927227
R1003	4.75K 1% 1/4W	MEP	5043	927247
R1004	1K 1% 1/4W	MEP	5043	927210
R1005	39.2K 1% 1/4W	MEP	5043	927339
R1006	5.62K 1% 1/4W	MEP	5043	927256
R1007	1.62K 1% 1/4W	MEP	5043	927216
R1008	18.2K 1% 1/4W	MEP	5043	927318
R1009	5.62K 1% 1/4W	MEP	5043	927256
R1010	1K 1% 1/4W	MEP	5043	927210
R1011	681 1% 1/4W	MEP	5043	928168
R1012	1.96K 1% 1/4W	MEP	5043	850219
R1014	3.32K 1% 1/4W	MEP	5043	927233
R1015	2.43K 1% 1/4W	MEP	5043	927224
R1020	10K 1% 1/4W	MEP	5043	927310
R1021	1.258K 0.1% 1/10W	MEP	5043	820212
R1022	150K 1% 1/4W	MEP	5043	927415
R1023	100K 10% Pot	BKM	72PMR100K	658410
R1024	1K 0.1% 1/8W	PRP	GP1/4W-T100	825210
R1025	90.9K 1% 1/4W	MEP	5043	927391
R1026	6.291K 0.1% 1/10W	PRP	GP1/4W-T100	820262

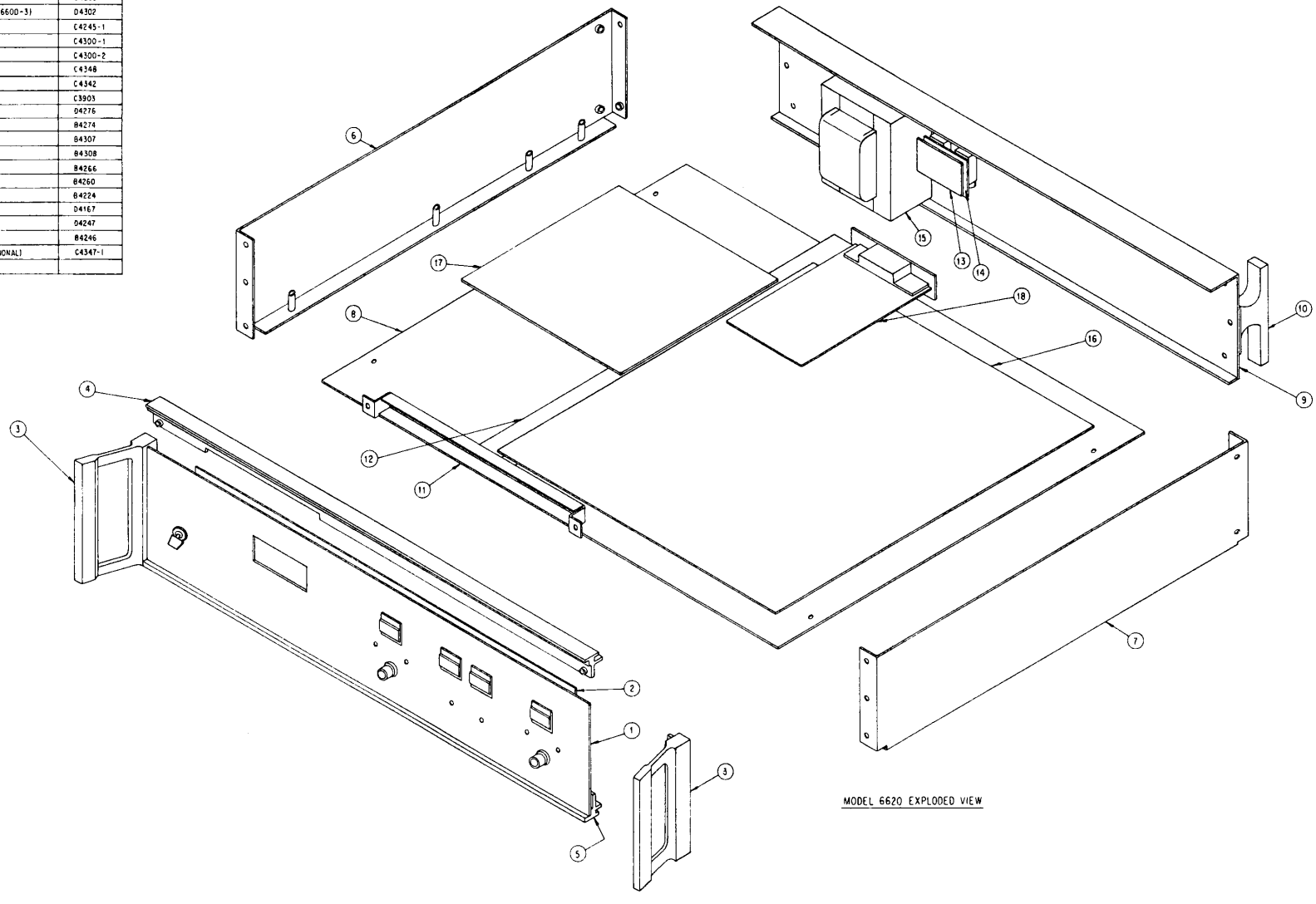
SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
R1027	Trim			———
R1028	8.2K 1% 1/4W	MEP	5043	927282
R1029	4.53K 1% 1/4W	MEP	5043	850245
R1030	20K 18 Turn Pot	BKM	68WR20K	655320
R1031	47.5 1% 1/4W	MEP	5043	927047
R1032	200K 1% 1/4W	MEP	5043	927420
R1034	909 1% 1/4W	MEP	5043	850190
R1037	10 1% 1/4W	MEP	5043	928010
R1050	75 1% 2W	AB	HB7505	957075
R1051	243 1% 1/4W	MEP	5043	927124
R1052	2.43K 1% 1/4W	MEP	5043	927224
R1053	500 10% Pot	BKM	72PMR500	658150
R1054	200 10% Pot	BKM	72PMR200	658121
R1055	1.21K 1% 1/4W	MEP	5043	927212
R1056	121 1% 1/4W	MEP	5043	928112
R1057	75 1% 2W	AB	HB7505	957075
R1060	27 10% 2W	AB	HB2701	958027
R1100	62 1% 1/4W	MEP	5043	927062
R1101	62 1% 1/4W	MEP	5043	927062
R1102	62 1% 1/4W	MEP	5043	927062
R1103	62 1% 1/4W	MEP	5043	927062
R1104	62 1% 1/4W	MEP	5043	927062
R1105	62 1% 1/4W	MEP	5043	927062
R1106	62 1% 1/4W	MEP	5043	927062
R1107	62 1% 1/4W	MEP	5043	927062
R1108	2.21K 1% 1/4W	MEP	5043	927222
R1109	2.21K 1% 1/4W	MEP	5043	927222
R1110	2.21K 1% 1/4W	MEP	5043	927222
R1111	2.21K 1% 1/4W	MEP	5043	927222
R1112	2.21K 1% 1/4W	MEP	5043	927222
R1113	2.21K 1% 1/4W	MEP	5043	927222
R1114	2.21K 1% 1/4W	MEP	5043	927222
R1115	2.21K 1% 1/4W	MEP	5043	927222
R1116	4.75K 1% 1/4W	MEP	5043	927247
R1117	4.75K 1% 1/4W	MEP	5043	927247
R1119	10K Pot	CST	B4256	631310
R1120	10K Pot	CST	B4256	631310
R1121	10K Pot	CST	B4256	631310
R1122	47.5 1% 1/4W	MEP	5043	927047
R1123	22.1K 1% 1/4W	MEP	5043	850321
R1124	22.1K 1% 1/4W	MEP	5043	850321
R1125	22.1K 1% 1/4W	MEP	5043	850321
R1126	22.1K 1% 1/4W	MEP	5043	850321
R1127	22.1K 1% 1/4W	MEP	5043	850321
R1128	22.1K 1% 1/4W	MEP	5043	850321
R1129	22.1K 1% 1/4W	MEP	5043	850321
R1130	22.1K 1% 1/4W	MEP	5043	850321
S1050	Switch Toggle	DGT	8280K27H	346535
S1051	Switch Slide	SW	46206LFR	346404B
S1052	Switch Slide	SW	46206LFR	346404B
S1100	Switch Pushbutton	DGT	SRV	344083
S1101	Switch Pushbutton	DGT	SRUL	344073

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
S1102	Switch Pushbutton	DGT	SRV	344083
S1103	Switch Pushbutton	DGT	SEAU0.A-GG	344072
S1104	Switch Pushbutton	DGT	SEAU0.A-GG	344072
S1105	Switch Pushbutton	DGT	SRV	344083
S1106	Switch Pushbutton	DGT	SRV	344083
T1050	Transformer	KH	B4224	361030
U73	Opamp	MOT	LF356N	200356
U76	Opamp	MOT	LF356N	200356
U104	Quad 2 In. Nand Gate	TI	SN74HC00	207400B
U108	Timer	MOT	LM555CN	200555
U112	Decade Counter	TI	SN74HC190	204190A
U119	4 To 10 Line Decoder	TI	SN74145	204145
U181	Comparitor Hi Speed	NS	LM360N	200360
U187	Comparitor Hi Speed	NS	LM360N	200360
U196	Opamp	MOT	LF356N	200356
U201	Opamp	MOT	LM308AN	200308
U224	Triac	MOT	CA3019	223019
U373	Opamp	MOT	LF356N	200356
U376	Opamp	MOT	LF356N	200356
U404	Quad 2 In. Nand Gate	TI	SN74HC00	207400B
U408	Timer	MOT	LM555CN	200555
U412	Decade Counter	TI	SN74HC190	204190A
U419	4 To 10 Line Decoder	TI	SN74145	204145
U481	Comparitor Hi Speed	NS	LM360N	200360
U487	Comparitor Hi Speed	NS	LM360N	200360
U496	Opamp	MOT	LF356N	200356
U501	Opamp	MOT	LM308AN	200308
U524	Triac	MOT	CA3019	223019
U611	Dual Multivibrator	TI	SN74LS123	204123
U615	Dual Multivibrator	TI	SN74LS123	204123
U625	Hex D Flip-Flop	TI	SN74174N	204174A
U632	Quad 2 to 1 MUX	MOT	MC10H158P	260158
U646	Quad 2 Input NOR Gate	MOT	MC10H102	260102
U656	Quad 2 Input NOR Gate	MOT	MC10H102	260102
U682	Opamp	MOT	LM308AN	200308
U683	Voltage Reference	MOT	LM399H	200399
U698	Voltage Reference	MOT	LM399H	200399
U720	Opamp	MOT	LM308AN	200308
U734	Opamp	MOT	LF356N	200356
U1000	MPU	MOT	MC6802P	206802
U1001	Eprom 8K X 8	MOT	D2764A	202764
U1002	3 To 8 Line Decoder	TI	SN74LS138N	204138
U1003	3 To 8 Line Decoder	TI	SN74LS138N	204138
U1014	PIA Timer	MOT	MPS6522	286522
U1015	PIA	MOT	MC6821P	206821
U1020	4 1/2 Digit DVM	MOT	SI7135	267135
U1030	Voltage Reference	MOT	LM399H	200399
U1037	Decade Counter	TI	SN74HC190	204190A
U1050	Regulator	MOT	LM317T	200317
U1057	Regulator	MOT	LM337T	200337
U1060	Regulator	MOT	LM323K	200323

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #
U1100	Hex D Flip-Flop	TI	SN74HC174	204174B
U1101	Display Green	MON	MAN6460	296460
U1102	Display Green	MON	MAN6460	296460
U1103	Display Green	MON	MAN6460	296460
U1104	Display Green	MON	MAN6460	296460
U1105	Display Green	MON	MAN6460	296460
U1106	Display Green	MON	MAN6460	296460
U1108	3 To 8 Line Decoder	MOT	MC74HC138N	204138A
VR189	Diode Zener 5.6V	MOT	1N752A	230752
VR207	Diode Zener 6.4V	CD	1N4577A Selected	264577
VR221	Diode Zener 6.4V	CD	1N4577A Selected	264577
VR489	Diode Zener 5.6V	MOT	1N752A	230752
VR507	Diode Zener 6.4V	CD	1N4577A Selected	264577
VR521	Diode Zener 6.4V	CD	1N4577A Selected	264577
VR692	Diode Zener 10V	MOT	1N961B	230961
VR727	Diode Zener 6.4V	CD	1N4577A Selected	264577
VR1034	Diode Zener 5.6V	MOT	1N752A	230752
Y1001	Crystal 4MHz 20PPM	MTN	MP-1	290400

SCHEM REF	DESCRIPTION	MFR	MFR PART NUMBER	KH PART #

ITEM	DESCRIPTION	X-H PART NO.
1	FRONT PANEL	C4298
2	FRONT PANEL (PC 6600-3)	D4302
3	HANDLE	C4245-1
4	FRONT RAIL - TOP	C4300-1
5	FRONT RAIL - BOTTOM	C4300-2
6	LEFT SIDE RAIL	C4348
7	RIGHT SIDE RAIL	C4342
8	BOTTOM COVER	C3903
9	REAR PANEL	D4276
10	REAR PANEL FOOT	B4274
11	FRONT RAIL BRACKET	B4307
12	PC MOUNTING BRACKET	B4308
13	LINE SWITCH SHIELD	B4266
14	LINE SWITCH PCB BOARD	B4260
15	TRANSFORMER	B4224
16	(PC 6600-1)	D4167
17	(PC 6600-2)	D4247
18	IEEE BOARD (STD.)	B4246
	RS 232-BCD BOARD (OPTIONAL)	C4347-1



MODEL 6620 EXPLODED VIEW